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ABSTRACT

The second report of the 'Buildings in Use' study documents the results of over 100 field tests conducted at four elementary schools, as well as discussion of these results and relevant technical specifications and details. The procedural framework used in the Field Tests Manual is followed and test results are rated numerically wherever possible. Technical factors compose the background environment that contains the very basic attributes: protection from the elements; suitable interior surfaces for the use of furnishings and equipment; thermal comfort and satisfactory auditory and visual conditions. (Author/MLF)

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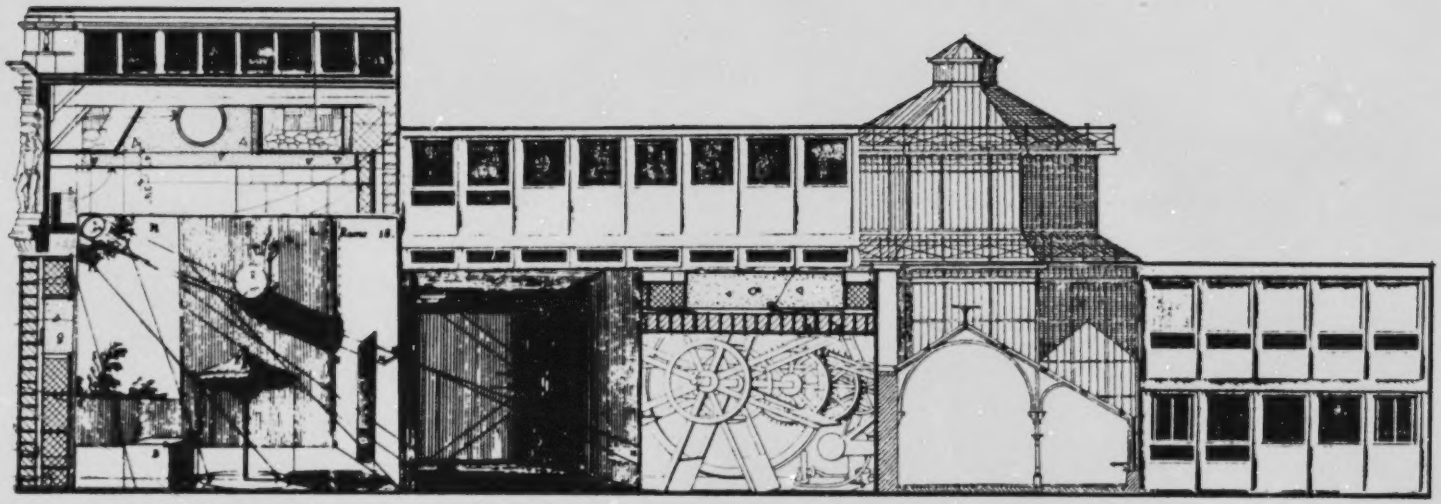
buildings in use study

technical factors



EA 009 244

PROJECT DESCRIPTION

The 'Buildings In Use' study is an attempt to examine, in the field, the performance of buildings which have been 'in use' for some time. We believe that such examination is the primary method through which better buildings can be designed. Three major factors are examined: technical performance, functional performance, and the relationship between environment and behavior.

This study has investigated four elementary schools in Columbus, Indiana. These schools, designed by nationally prominent architects, were completed in 1962, 1966, 1969 and 1972. The two older schools contain traditional classrooms; the two more recent buildings utilize semi-open (1969) and open (1972) educational and design concepts. The schools are similar in size (500-600 students) and in the social characteristics of their students.

Technical studies have been carried out in the following areas: exterior walls, roofs, interior walls, floors, ceilings, acoustics, lighting and H.V.A.C.. A "Field Test Manual" has been developed which was actually the basis for testing the technical performance of the buildings. The results of these field tests, as well as discussion of these results and relevant technical specifications and details are documented in the "Technical Factors Report". Over 100 tests and the results of these tests are included in the two reports.

Functional studies include areas of 'activity support' exclusive of furniture. This includes studies of specialized areas and functions within the school as well as storage, classroom display, window usage and some activity support equipment. Measures in this area include capacity, anthropometric fit and amount of usage. Results will be reported in the "Functional Factors Report".

Behavioral studies have been carried out using observation supplemented by questionnaires and interviews. This aspect of the study was aided by participation of faculty from UWM's School of Education. Research questions concerning differences between schools in terms of groups size, type of activity, seating, student posture and spatial usage are addressed as well as studies within schools such as the effect of proximity and territoriality. Results are documented in the "Behavioral Factors Report".

The documentation of this study will be available in early 1976. This information is directed to architects and clients in order to help them make the consequences of programming and design decisions more predictable. Researchers in this area will be interested in the concepts and methods of this study as part of the larger effort to accumulate experience and findings which have the goal of developing a body of theory and procedure in this field. Reports of this project, funded by a grant from the Irwin-Sweeney-Miller Foundation and the Bartholomew Consolidated School Corporation (Columbus, Indiana), are available from Harvey Z. Rabinowitz, Project Director, School of Architecture and Urban Planning, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201.

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INTRODUCTION

THE STUDY

Those responsible for building design rarely examine, in a formal and comprehensive manner, the environment they have helped create. We believe such examination is, however, the primary method through which better buildings can be created. Thus, what we learn from this study can be used, by clients and architects, in the design of future buildings.

This report is one product of the 'Buildings In Use' Study. The overall study examines architectural attributes of existing buildings (in this case 4 elementary schools) in order to determine how they have performed technically and functionally, and the relationship between the environment of the building and the behavior of its user population. This particular document addresses only the technical factors aspect of the study.

FIELD TESTS MANUAL

The technical factors evaluation is based on another document produced as part of this overall study: the Field Tests Manual. This report includes detailed descriptions of the tests used in the examination of the buildings. These tests are, for the most part, field test equivalents of National Bureau of Standards,

A.S.T.M., and Federal Specification Laboratory Tests and procedures.

There has been very little research performed in the comprehensive and formal evaluation of technical performance, much less of functional and behavioral factors, in existing buildings. The most notable work in this area is that of the Building Performance Research Unit at the University of Stratchclyde and the Pilkington Research Unit, University of Liverpool, both of whose efforts and reports were the precursors of the present 'Buildings In Use' Study.

In this 'hard' area of technical factors evaluation (in contrast to the 'softer' area of functional factors, and the even softer behavioral factors) we have adopted a formal and methodological approach. The procedural framework used in the Field Tests Manual is followed and test results are rated numerically wherever possible.

CRITERIA

Criteria used in judging technical performance were based on the premise that each subsystem of the building should perform as unobtrusively and reliably as possible. These subsystems, we feel, comprise the 'background' environment which should allow, but neither hinder nor stimulate, natural and typical activities to occur.

Highly reliable subsystems performance is expected, given routine maintenance and accounting for typical wear and tear. School administrators, teachers and students should be concerned with learning and not with building associated problems and repairs.

The following scale is used to indicate performance levels based on the stated assumptions:

○ 95% performance level, implying very satisfactory performance;

⊙ 85% performance level, implying minor performance problems which do not affect the activities within, or the image of, the building. Correctable by routine maintenance and/or repair;

Unacceptable is a:

● 75% performance level, implying major problems having some detrimental effects on the activities within, or the image of, the building. Correctable only by means of major repair or replacement procedures.

CONTEXT OF TECHNICAL FACTORS

Technical factors comprise the background environment which contains the very basic attributes: protection from the elements; suitable interior surfaces for the use of furnishings and equipment; thermal comfort and satisfactory auditory and visual conditions. They do not directly support activities, such as a blackboard, for instance, does. Flexibility, manipulation of environment (e.g. windowshades), storage and equipment are classified as direct activity support and are treated in another aspect of our study (functional factors).

Today's state of the art in design and construction produces a sound building with one or two or three major problems (below the 75% performance level) during its useful life. The elementary schools studied are not inconsistent with this performance. Though expected, major problems are unnecessary, unwanted and costly to resolve. Such problems also can be the basis for legal actions against the architect and/or contractor.

From the architect's viewpoint as a professional, the decisions he makes should have predictable and appropriate consequences in terms of performance, notwithstanding whether this desired performance is in the realm of technical factors, behavioral factors, perception or imagery. As a professional and a businessman, he must inform his client when client decisions, such as budget, will compromise appropriate performance. This 'service' to the client and the eventual user can protect the architect from future recrimination and legal action. Furthermore, the architect should, when given supervisory responsibility, not allow appropriate performance to be compromised through the construction process, notwithstanding the 'give and take' in that process.

To the architectural profession, many of whose members are wondering where their next project is coming from, such concepts as performance, technical analysis of existing buildings, much less behavioral studies, may not be particularly relevant. This type of study, however, seems to bridge the gap between research and practice. The results can be immediately applied as additional useful input into technical design decisions as well as providing a useful base and direction for continuing research. We believe that technical evaluation adequately documented and disseminated, serves both the needs of the professional today and is part of a new tradition in the practice of architecture.

COMMENT ON THE TECHNICAL DATA AND FINDINGS

1) Wherever possible information on the existing building is based on the original working drawings and specifications. The reader should note that changes in design and construction are often made subsequent to these original documents. Since 'as built' drawings are not available and changes have occurred, it is possible that some of our findings, especially in the area of 'probable cause' may be erroneous.

2) Many potential causal factors and combinations of such factors effect the problem situations noted in this report. We have drawn on as many sources to help aid in our analysis of each performance characteristic. In some cases a number of probable causes are mentioned because of the complexity of the situation. However, we do not in any way guarantee our findings or the performance of the buildings or their subsystems in the future.

3) The severity of the findings is documented for all results. The reader should be cautioned to read this carefully and retain perspective on particular items. Some lengthy discussions may, in fact, pertain to less significant defects of only academic interest. The summary of performance indicator at the beginning of each chapter quickly indicates the overall level of performance and levels for specific tests.

NOTES AND REFERENCES

- "Building Performance", Building Performance Research Unit. Applied Science Publishers, Essex, England, 1972.
- "Office Design: A Study of Environment", Pilkington Research Unit. University of Liverpool, England, May, 1965.
- "The Primary School: An Environment for Education", Pilkington Research Unit. University of Liverpool, England 1967.

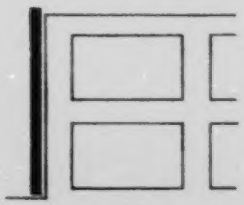
These reports are by two of the pioneering groups in the building evaluation field which who include technical factors in their evaluation.

- "Economics of Carpeting and Resilient Flooring", Geo. M. Parks. Wharton School, University of Pennsylvania Press, 1966.

The 95%; 85% 75% performance criteria and methodology are based on the system developed in this important study.

EXTERIOR WALLS

INTRODUCTION



The exterior wall performs several diverse functions simultaneously: when load-bearing, it provides physical support for the structure; it exists as the principal barrier between interior and exterior space and their frequently widely-differing environments; and its exterior surface and configuaration constitute much of the public image of the building it encloses.

Subject to various structurally-induced stresses and strains, constantly exposed to the elements and to public scrutiny, the exterior wall subsystem is one of the most difficult to design for continuing, satisfactory performance over the life of the building. Exterior windows and doors further complicate design, detailing and construction. Despite these complications, failures of this subsystem are infrequent.

The examination of the exterior wall, in the context of the 'Buildings In Use' Study, is confined to the investigation of performance in the areas of durability, weathertightness and appearance, and to attributes which affect performance in those areas. There are numerous generic materials commonly used in this subsystem, and the findings are discussed separately under the following materials-oriented categories: brick and concrete masonry; in-situ concrete; and curtain walls and other openings.

METHOD OF EXAMINATION

Visual observation was the primary method of examination in all schools. Their exterior walls were examined to determine what, if any, movement had occurred since completion of the structures, and how well the materials and systems used had weathered. The 'fit' between individual components within the various wall systems was also examined quite closely.

Equipment used in examining and testing of the exterior walls included: a plumb line, to check for wall deflection; a small rule calibrated to 1/64 inch, to measure the width and depth of cracks; a measuring tape, to determine the length of walls and cracks in them; and a camera, to record instances of deterioration.

For a more detailed description of the testing procedures used, refer to the Field Tests Manual, 'Buildings In Use' Study, December 1974.

A comparison of the measures and observations was made with existing standards to determine the quality of performance.

SUMMARY OF PERFORMANCE

	P	R	S	M
EXTERIOR MASONRY				
Structural Stability	O	⊙	NA	O
Thermal Stability	O	⊙	NA	O
Other Stabilities	O	⊙	NA	O
Air-Moisture Penetration	O	O	NA	⊙
Stain/Discoloration	⊙	O	NA	O
Deterioration	O	O	NA	O

					A-3
	EXTERIOR CONCRETE				
	Stability	NA	NA	O	NA
	Air-Moisture Penetration	NA	NA	O	NA
	Stain/Discoloration	NA	NA	O	NA
	Deterioration/Delamination	NA	NA	O	NA
	CURTAIN WALLS				
	Structural-Thermal Stability	O	O	O	O
	Air-Moisture Penetration	O	O	⊙	⊙
	Stain/Discoloration	O	O	O	O
SUMMARY OF FINDINGS	Deterioration/Delamination	O	O	O	O

Brick masonry exterior walls with block back-up were used extensively in three of the four schools studied. The difference in the specifications of these similar products, their storage conditions and their detailing and construction all influence performance during the useful life of the subsystem. Problems (below 85% performance level) were found at the Richards School. Conditions which bear watching wre found at Mt. Healthy. The Parkside School was generally satisfactory (85-95%).

Movement and attendant minor cracking due to a number of factors--structural loading, thermal expansion/contraction and shrinkage--were found at numberous locations at the Richards School. However, only a few of these cracks due to movement cause more than aesthetic problems. Some minor movement due to thermal expansion is also taking place at one or two locations at

Mt. Healthy. At certain locations at Mt. Healthy School the brickwork is very badly fitted. Future deterioration is probable at these locations and only time will tell, in this relatively new facility, whether real problems will emerge. The Parkside School, aside from minor areas of efflorescence, is in excellent condition.

The concrete exterior walls of the Smith School perform satisfactorily in all respects. Though extensive staining and discoloration is present and would, under normal circumstances, affect aesthetics, the intention of the architect was to allow, possibly even encourage, such occurrences. Thus, what in a normal context would be judged unsatisfactory is acceptable, even desirable, under these circumstances.

Performance of the Cor-ten curtain wall at the Smith School is satisfactory based on the same criteria used in judging the concrete exterior wall at that school.

The performance of door and window openings of the exterior wall in all schools is generally good. The doors at the Richards School are ill-fitted and do allow some air and moisture infiltration.

In all buildings studied children have dug caulking out of window framing. Caulking is rubbery and fun to throw.

Routine maintenance is necessary on the ramps of the Smith School. After some 5 years of exposure the paint is chalking and in some cases flaking (this has just been repainted!). Polyurethane insulation, sprayed on the undersides of exposed slabs is undergoing deterioration and is flaking and falling off in places.

DETAILS OF FINDINGS

EXTERIOR MASONRY

EXTERIOR MASONRY WALLS/STABILITY, STRUCTURAL LOADS (Fig. A.5)

Results: Performance was satisfactory at the Parkside and Mt. Healthy Schools. Performance at the Richards School was at the 75-85% level due to cracking evident under major roof truss supports in the multipurpose room.
Probable cause: Richards School. Probably due to actually higher loads than allowable under original design conditions or to expansion of restrained truss.
Discussion: There is a long vertical stepcrack emanating from each of the lowest spanning trusses of the multipurpose room. The cracking is long (over 10' is typical), visible but minor (1/16" or less). Due to the age of the building one can assume that this structural adaptation has been completed and that further consequences will not occur. There are no problems other than aesthetic directly related to this phenomonon, however, there are more serious indirect effects (see roofs). The probable cause of this phenomenon is an excessive loading on this lowest truss due to water trapped in the drainage valley directly above it. Other possible causes are: bearing seat improperly specified or installed; transfer of some loading from upper trusses to this one and; high stresses caused by thermal expansion and the restrained nature of these trusses (see Roof P. B-5).

EXTERIOR MASONRY WALLS/THERMAL STABILITY (Fig. A.6)

Results: Performance was satisfactory at the Parkside School. Some minor accommodation in the exterior wall at Mt. Healthy has taken place. The performance was below the 75% level at the Richards School. Expansion of roof truss over the multipurpose room causes wall movement which, in turn, causes moisture infiltration.
Probable cause: Lack of provision for the expansion of a long span truss.

Discussion: Mt. Healthy. At two locations the exterior wall is continued out of the building for some distance and that portion is exposed to the elements on both sides. The varying rates of expansion of the two portions of wall which are continuous implies some accommodation, since there is no expansion joint between the two portions. Some hairline cracking has occurred, however, this should be the extent of accommodation due to the use of horizontal reenforcement in the walls. This reenforcement should adequately absorb all thermal stress and minimize movement of the wall which otherwise would have caused major problems.

At the Richards School, a number of problems due to thermal movement have occurred. The first concerns the roof trusses spanning the multipurpose room. These 54 foot trusses are restrained at their ends causing wall movement and real leakage problems as described in the 'Roof' section of this report (See P. B-7).

Two other minor, but easily visible effects have occurred due to thermal expansion/contraction. These are primarily of academic interest because they are primarily aesthetic problems and visible primarily to researchers.

The long (78 feet) north-south wall forming the eastern end of the school has expanded and cracked the two perpendicular walls at their common T-joint. This cracking, while easily visible is minor and is only an aesthetic problem. This long wall, while designed without an expansion joint is broken up by entrance doors and an air intake grill. Notwithstanding these potential places which could have provided relief from expansion the wall did expand (fig. A.6)

At the west end of the school there are two wings with 84 foot masonry walls perpendicular to the main body of the building. Though an expansion joint is provided at this juncture there is easily visible, though functionally harmless, cracking at this T-joint. Though we have not dissected this area we believe a logical explanation is an incorrectly constructed joint which

allows a rigid connection at the point and in essence not allowing proper expansion.

EXTERIOR MASONRY WALL/STABILITY (OTHER) (Fig. A.8)

Results: In certain classrooms adjacent to 'stub' corridors there is a consistant, though minor, cracking at the caulked joint of the two walls.
Probable cause: The two walls are probably 'tied' at this T juncture and since no expansion joint is provided the exterior wall has moved causing a slight separation.
Discussion: Though visible (1/16"-1/64") these cracks are not functionally detrimental. Properly recaulked and painted they would probably not reoccur.

EXTERIOR MASONRY WALL/AIR-MOISTURE PENETRATION

Results: The varied phenomena noted in the previous sections have not resulted in air and moisture infiltration.
Probable cause: Not applicable.
Discussion: Not applicable.

EXTERIOR MASONRY WALL/STAIN AND DISCOLORATION

Results: Performance levels of exterior masonry walls were satisfactory in this regard at all schools except Parkside where some efflorescence has occurred.
Probable cause: Dissolved salts in the brick (or sometimes mortar) leaching out on to the surface.
Discussion: This is not an infrequently found condition. Though correctly specified and installed, efflorescence of masonry exterior wall may still occur. Knowledge of the quality control of the manufacturer and the use of a 'hard' brick which is more resistant to moisture penetration would

help to reduce the probability occurrence of this white staining on the brick's surface, but not necessarily prevent it.

EXTERIOR MASONRY WALL/DETERIORATION

Results: Performance was satisfactory at all schools.
Probable cause: Not applicable
Discussion: Not applicable

EXTERIOR CONCRETE

EXTERIOR CONCRETE: STABILITY (ALL ASPECTS)

Results: Performance was satisfactory.
Probable cause: Not applicable
Discussion: Not applicable

EXTERIOR CONCRETE: AIR AND MOISTURE PENETRATION

Results: Performance was satisfactory.
Probable cause: Not applicable
Discussion: Not applicable

EXTERIOR CONCRETE: STAIN AND DISCOLORATION

Results: Performance was satisfactory.
Probable cause: Not applicable
Discussion: Smith School. As mentioned in the Summary of Performance staining of the in situ concrete would not hinder performance--not even aesthetic performance, and indeed staining of the concrete is extensive due to the initial rusting of the Cor-ten steel.

EXTERIOR CONCRETE: DETERIORATION/DELAMINATION

Results: At the Smith School there are one or two individual instances of serious deterioration of the exterior concrete surfaces which should be corrected.
Probable cause: The overall low, or 'brutal' quality of the finish as specified by the architect has resulted in a few places in which performance is affected.
Discussion: A low quality of finish for the in situ concrete is acceptable, even encouraged, in this building for reasons mentioned previously. Thus, patches, spalling, honeycombing and formwork markings are plentiful and acceptable. However, at the exit ramp leading from the 3rd and 4th grade levels the concrete supports have 'lost' enough material to cause exposure of the reinforcement, perceptable movement of the bearing plate and some displacement in the ramp itself. Over time this will become serious and we recommend correction as soon as possible.

CURTAIN WALLS

CURTAIN WALLS: STABILITY (STRUCTURAL/THERMAL)

Results: Performance levels were satisfactory in this regard at all schools.
Probable cause: Not applicable
Discussion: Not applicable

CURTAIN WALLS: AIR/MOISTURE PENETRATION (Fig. A.9)

Results: Performance levels were marginally acceptable at most facilities studied (85%). Severe weather and windblown rain does cause instances of water infiltration but these occurrences are infrequent. The fit of the exterior doors at Richards is not tight enough to prevent air infiltration--this is correctable. At the Smith School water flowing down grooves in the metal wrapped sloping ramps has penetrated through the seal at the lower ends

of the ramps and has entered the building. This has been corrected.
Probable cause: The original detailing, weathering and the removal of caulking by students have all contributed to deteriorated performance.
Discussion: The level of performance required of this subsystem does not permit air and water infiltration even during severe weather. Thus even the minimal occurrences of problems which were found constitute a lower level of performance. At the Richards School this is a problem in a few classrooms. The original exterior doors were 'hollow core' type, failed, and were replaced with solid core exterior doors, some of which may need refitting and weather protection.

At the Smith School the detail at the lower end of the sloped ramps is extremely difficult to solve with the use of the corrugated steel exteriors. The water races down the valleys of the corrugated metal exterior and is directed with some force at the joint with the curtain wall which could not perform adequately. The original detail has been modified with silicone caulk which seems to be performing adequately. It should be noted that the working drawings examined used the corrugated steel wound around the ramp which would have simplified the detail. The ramps were built with the metal corrugations running longitudinally.

At Mount Healthy recaulking is now taking place. The original material used on the industrial sash is dry and coming loose allowing water to enter.

CURTAIN WALLS: STAINING/DISCOLORATION

Results: Performance levels were satisfactory at all buildings examined except at Smith where extensive chalking of the painted steel ramp siding is evident.

Probable cause: Weathering.
Discussion: Chalking is a normal result of weathering of a painted surface. The ramps need repainting.
NOTE: They have just been repainted (1974).

CURTAIN WALLS: DETERIORATION/DELAMINATION

Results: The removal of caulking from window frames is present at the Smith, Parkside and Mount Healthy Schools. Normal deterioration of the wooden window frames is present at Richards. The original exterior hollow core doors at the Richards School deteriorated within one year of occupancy and were replaced with solid core doors. With these exceptions, performance levels were satisfactory. The galvanized industrial sash glazing at Mount Healthy is beginning to rust in spots. This is being repainted as a preventive measure.
Probable cause: Kids dig out caulking from around windows. Weathering has caused deterioration of Richards frames.
Discussion: The removal of caulking by kids at three of the facilities is surprising. Subsequently we noted similar situations at elementary schools in other localities. We are no longer surprised by this phenomenon. Covering the caulking with a metal strip, which has been used at the Smith School is effective in preventing occurrences, as is the use of hard or preformed gasketing such as a neoprene gasket or an elastomeric sealant such as polysulfide or silicone. Caulking materials which are easily removed and fun to throw or which have 'play' potential should not be used.

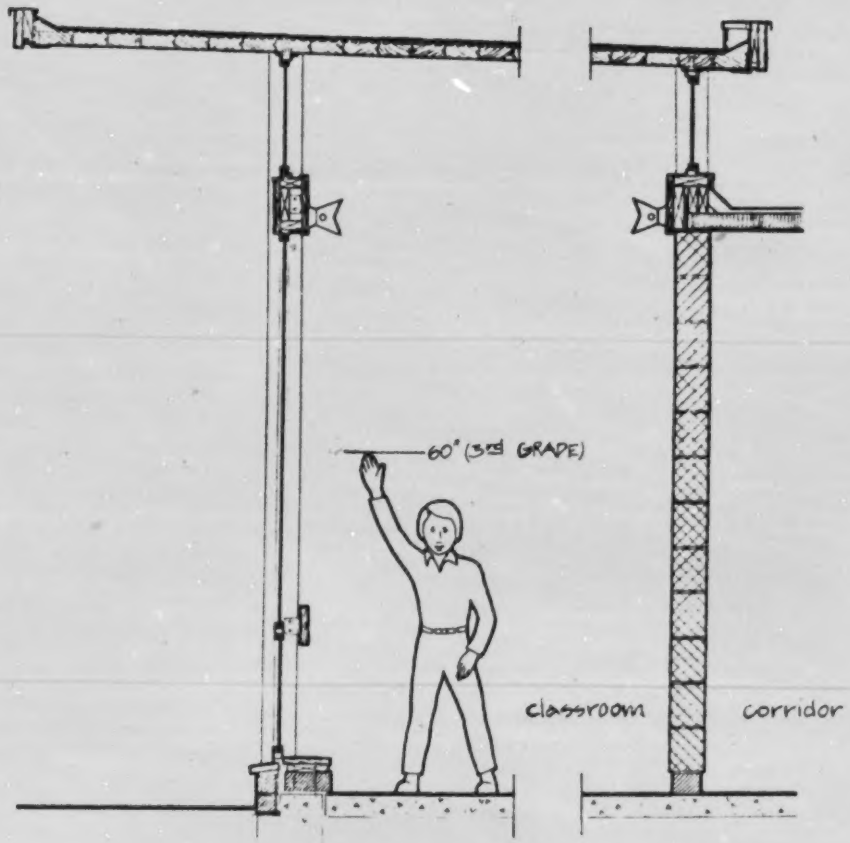


fig. A.1
PARKSIDE SCHOOL/SECTION

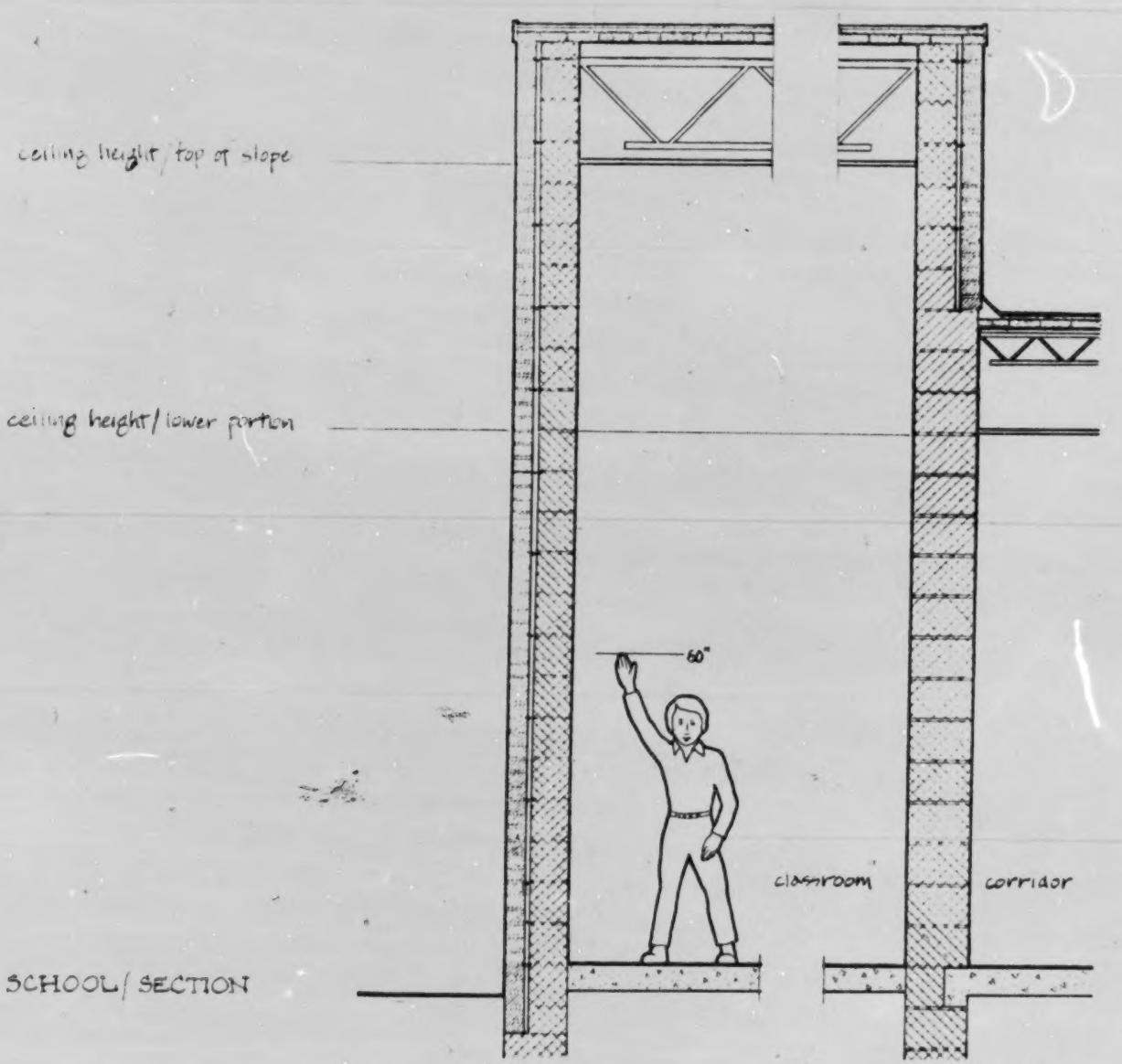


fig. A.2
RICHARDS SCHOOL/SECTION

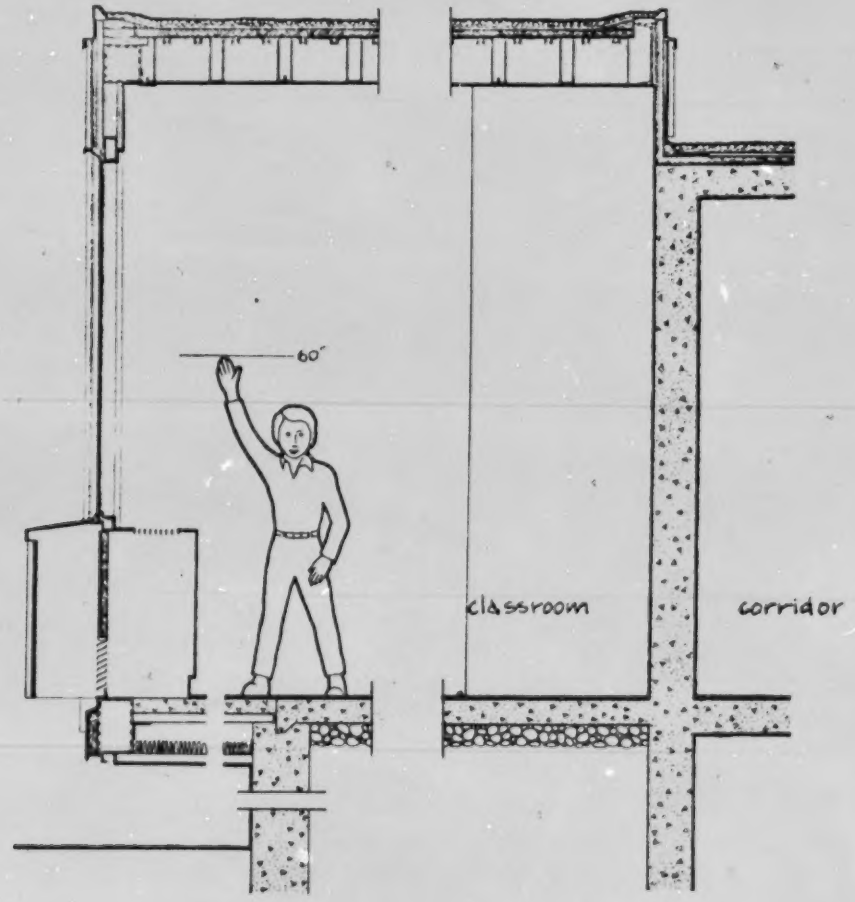


fig. A.3
SMITH SCHOOL/ SECTION

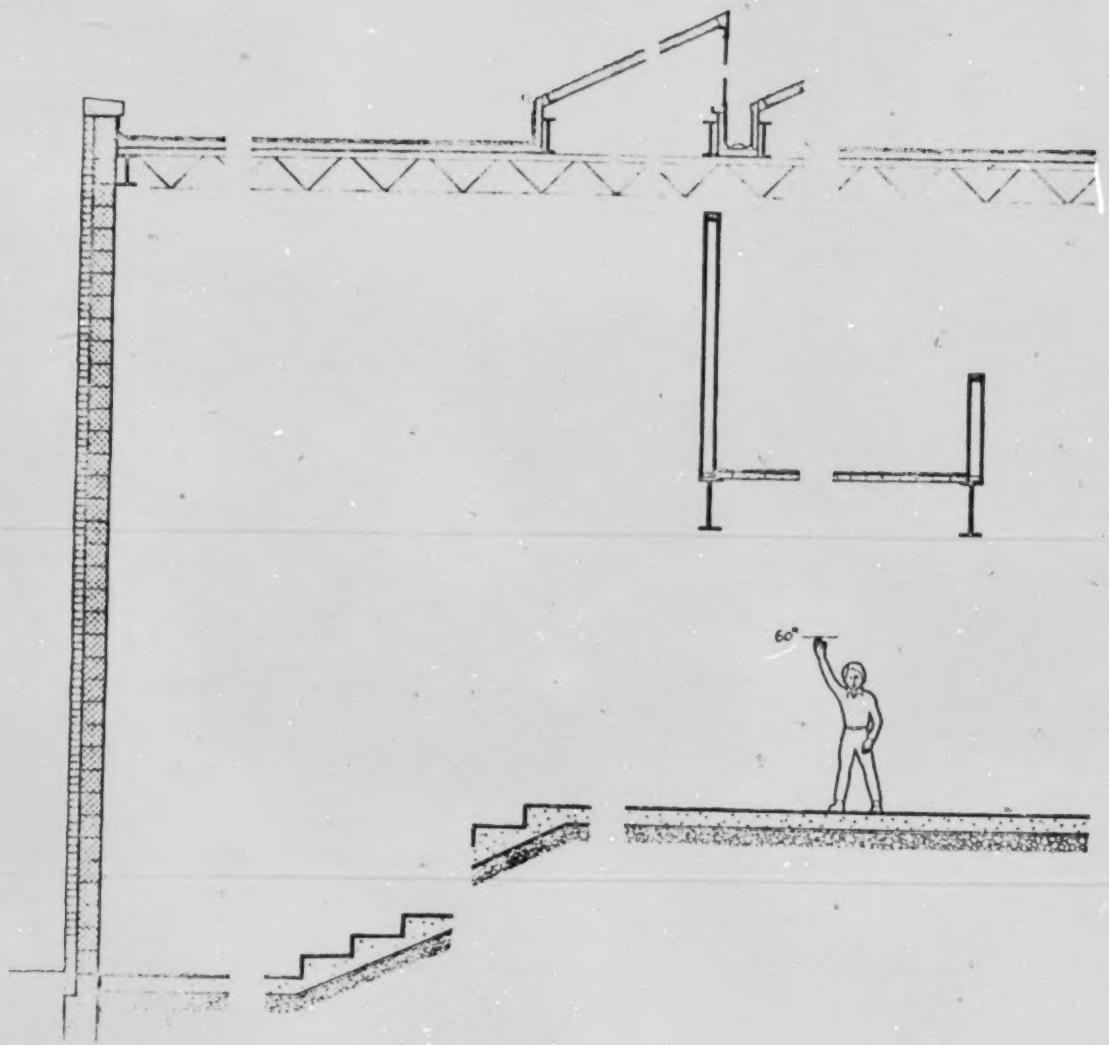


fig: A.4
MT. HEALTHY/SECTION

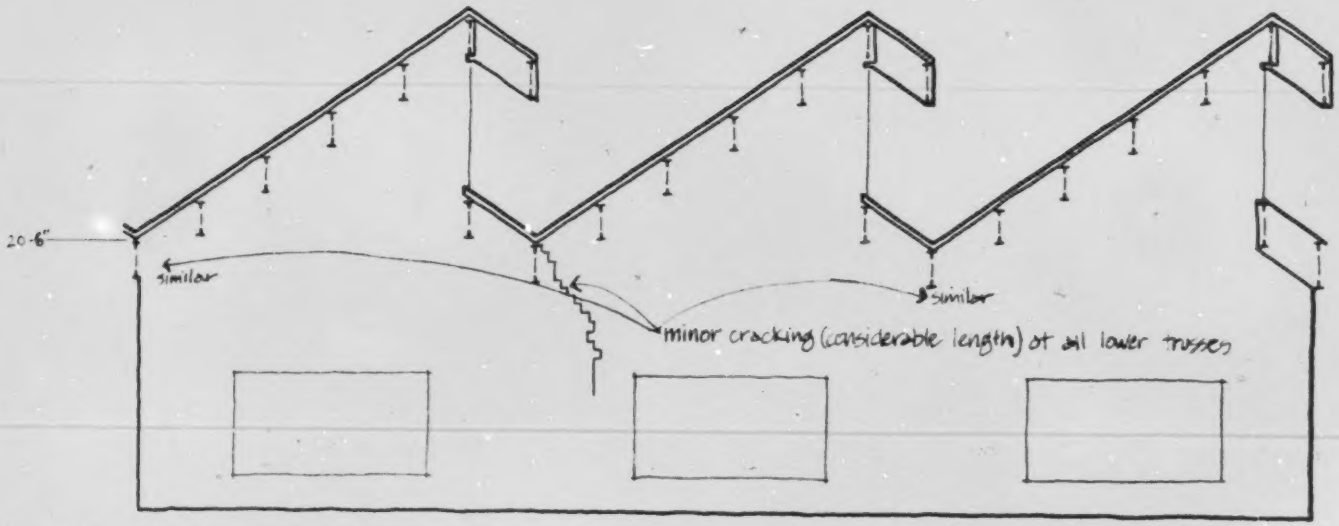
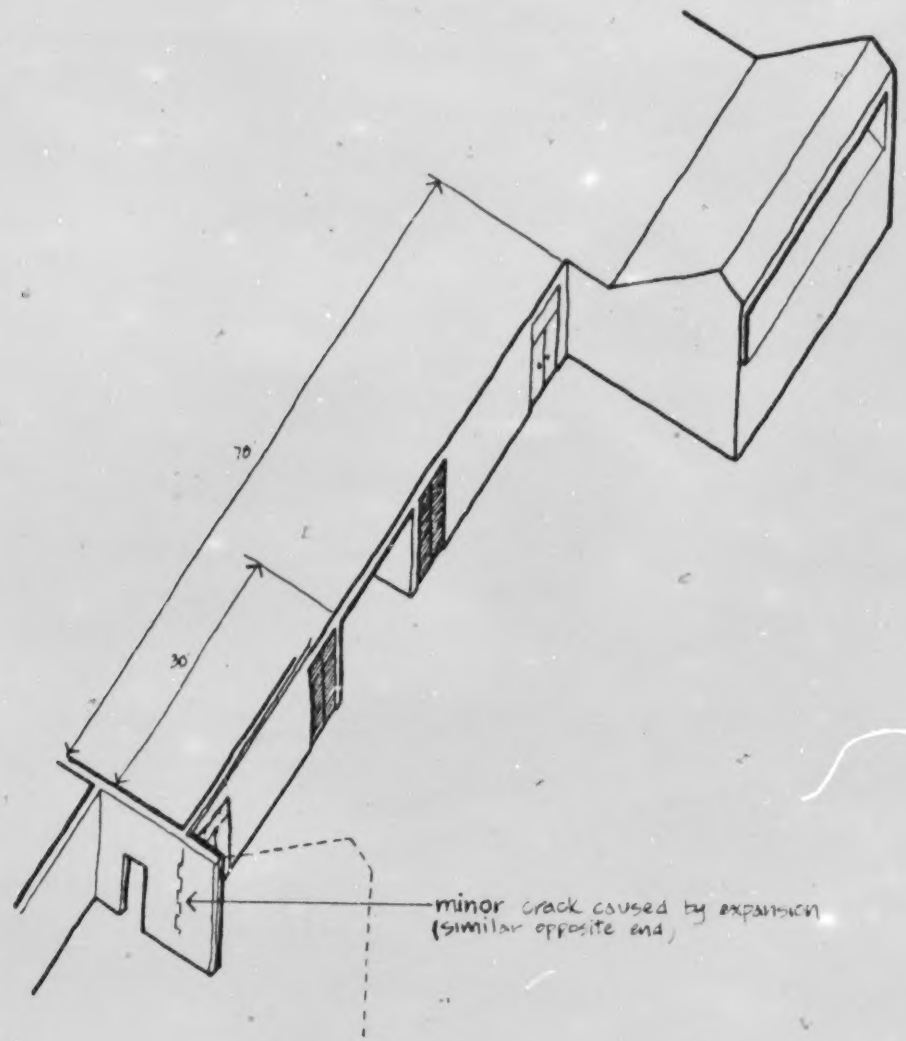


fig. A.5
RICHARDS SCHOOL / SECTION - MULTIPURPOSE ROOM

fig. A.6
RICHARDS SCHOOL/EAST END



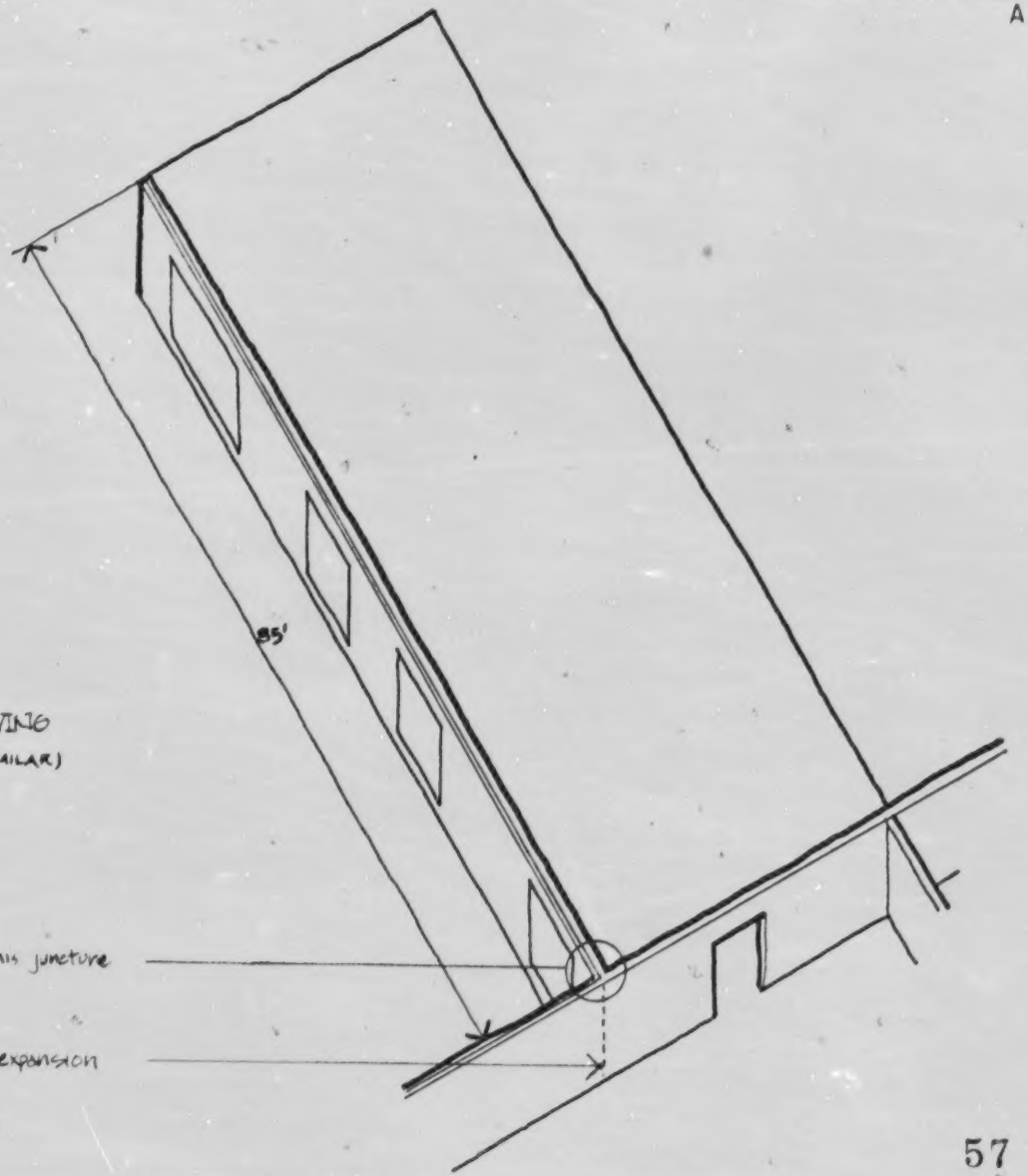


fig. A.7
RICHARDS SCHOOL/NORTHWEST WING
(SOUTHWEST WING SIMILAR)

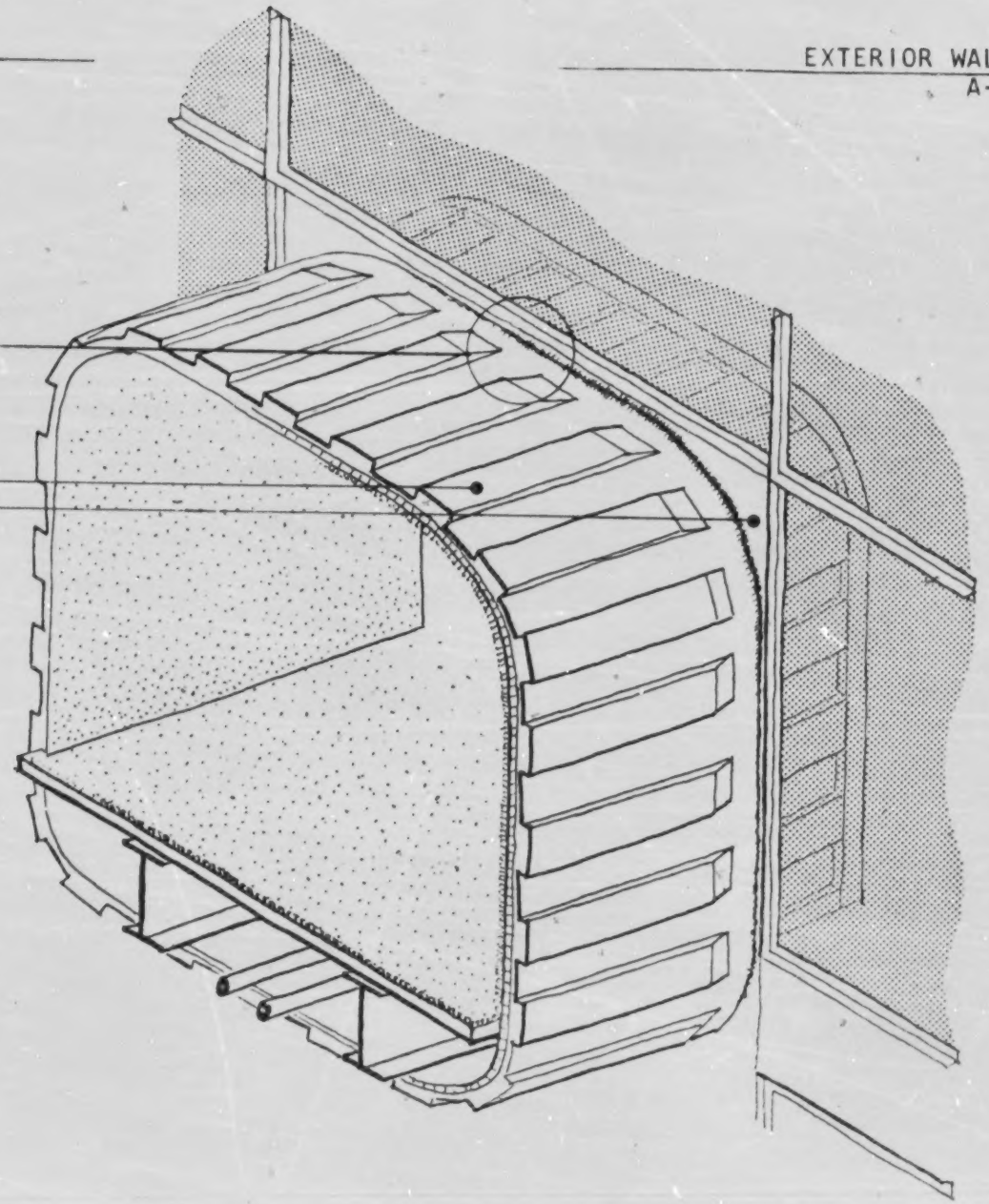
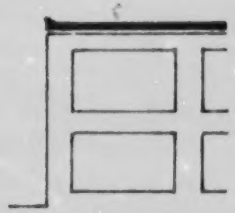

water running down sloped corrugations enters via weld line or sealant (corrected)
corrugated steel siding
10 ga. steel gusset

fig. A.8
SMITH SCHOOL/SLOPED RAMPS

ROOFS

INTRODUCTION



The primary objective of the roofing membrane is to absolutely keep out weather - primarily moisture. To satisfy this objective the most critical attribute of this system is to prevent any moisture penetration which may occur through improper design, faulty construction practices or through weathering action on this tenuous membrane.

The roofing membrane is the most 'sensitive' of all the building subsystems examined in this study. This is due to its having a constantly high exposure to the elements; the nature of water's insidious ability to infiltrate into a building and the numerous possibilities for error in design and construction.

Since this is so tenuous a membrane a reasonable course of action would be towards overdesign for moisture protection, very careful supervision of construction, and, getting the water off of the roof as quickly as possible.

METHOD OF EXAMINATION

Very rigorous measures and a detailed visual examination were made of this membrane. Evidence of moisture penetration was of prime importance as was evidence of weathering and entrapped air and moisture.

A 4' level, inclinometer and small rule calibrated to 1/32" were used to measure pitch, depth of standing water and deterioration. For a more detailed description of testing procedures used refer to the Field Tests Manual, 'Buildings In Use' Study, December 1974. A comparison of these measures and observations with existing standards was used to determine the quality of performance.

SUMMARY OF PERFORMANCE	P	R	S	M
DRAINAGE				
Ponding	O	●	O	O
Details	O	⊙	⊙	O
Roof Slopes	O	●	⊙	O
MOISTURE PENETRATION				
Details	O	O	O	●
Movement	O	●	O	O
DETERIORATION EROSION	O	●	O	⊙
IMPACT/INDENTATION/ BRITTLENESS	⊙	●	O	O

SUMMARY OF FINDINGS

The roofing membrane is one of the most tenous systems in any building. Roofing failure is a serious and frequent problem in any facility. Such failures are due to many causes: incorrect detailing, poor quality materials, improper construction practices, effects from other building subsystems, etc. None of these are without remedy in existing buildings nor unpreventable in future new construction.

The performance of the built-up roofing membranes of the four buildings studied was mixed. The Parkside roof is "the best in the district" (85% level) and the Mt. Healthy roof is generally satisfactory (75-85% level). The Smith School is rated at the 75%-85% level because of a potential for future problems though it is now performing satisfactorily. The Richards School is rated at below 75% becuase of numerous problems resulting from detailing, construction and deterioration during the life of this building.

No convergence of problem types is present. What exists is a cornucopia of causes, many of which are 'textbook cases'.

DETAILS OF FINDINGS

DRAINAGE

DRAINAGE/PONDING (Figure B.1 through B.4)

Results: Performance was generally satisfactory at the Parkside and Mt. Healthy Schools. Ponding due to inadequate drainage is a problem at the Richards (below 75%) and the Smith (85%) Schools. Within 1 year of occupancy all of the built up roofing at Richards had already been replaced when core samples revealed total saturation of the roof membrane and insulation. Richards Elementary School has the most extensive ponding closely followed by Smith. Roof construction at Smith is of such high quality, which is rare, that existing ponding does not now, and may not, cause future moisture penetration. The Richards School has a less well constructed roof and alligatoring, brittleness and membrane movement due to ponding caused many problems in the past and may well cause future problems.

Probable cause: No slope or inadequate slope specified in the original design is the major cuase of ponding.

Discussion: The main concern of the designer should be getting the water off of the roof. Ponding consists of substantial amounts of water which do not drain off of the roof surface. This can immediately cause leaks if the roof is not 'tight'. Even more insidious, however, is the deterioration of the membrane due to ponding. Freezing of this standing water, which is, of course, relatively shallow and easily frozen, can literally tear the roofing membranes. The more typical effect, however, is movement of the membrane caused by a temperature differential between the exposed roofing, which on a sunny day may be 180 degrees and the membrane under the pond which is substantially lower in temperature. Other effects of ponding are erosion of the protective gravel surface and alligatoring-minute cracking of the membrane. Moisture penetration is a cause of blistering, caused by expansion of the water vapor, and also a cause of roofing movement due to water vapor migration between the felts.

Specifying minimum slopes (1/8 inch/ft.) can be nullified by settling, construction tolerances, workmanship during construction or roof sag during the life of the building. In fact some roofs specified to slope towards the roof drain were found to actually slope away from the drain because of the above mentioned factors.

DRAINAGE/DETAILS (Figure B.6)

Results: Performance was adequate at all facilities examined. Drains can sometimes be higher than the roof surface due to additional flashing and therefore cause or exacerbate ponding conditions. Gutters between adjacent skylights at Mt. Healthy were found to be a trap for leaves and a potential source of blockage.
Probable cause: Architectural detailing and construction tolerences due to flashing, protection around drains.
Discussion: Typically all openings through the roof are protected by additional layers of roofing felt and flashing materials. This causes the roof to pitch up slightly at the drain. If a drain is chosen or installed in a manner which also raises it above roof level--the combination of the higher drain and the additional protection can actually be 2-3" above the roof level which will cause ponding in this location.

DRAINAGE/ROOF SLOPES (Figure B.1 through B.4)

Results: Performance was satisfactory (85%) at Mt. Healthy, at the 85% level at Parkside, but unsatisfactory (75% or below) at the Smith and Richards Schools where a lack of slope results in ponding.
Probable cause: Design did not specify sloped roofs.
Discussion: This, of course, is the primary couse of ponding. 'Dead' flat roofs were specified at the Smith and Richards Schools. At Richards the roof actually slopes away from the drain. This, we believe, is caused by some small amount of settlement in the exterior wall or poor construction which at

first caused minor ponding. The weight of this additional water gradually caused the roof membrane to sag in this area and increased its capacity to hold water, producing a cycle of increasing ponding.

The Smith School has two roof levels over each typical wing, the higher draining via scuppers to the lower on which are located the roof drains. Ponding is extensive on the upper roof levels. Extensive water protection raises the roof edges enough to prevent water from reaching the scuppers. This results in an extensive pond at the center of each upper roof area. The roof construction, though, is excellent and does not allow any moisture penetration.

MOISTURE PENETRATION

MOISTURE PENETRATION/DETAILS (Figure B.5)

Results: Performance was satisfactory (85%) at Parkside and Smith, unsatisfactory (below 75%) at Richards and Mt. Healthy. Detailing permitted water to penetrate the roof.
Probable cause: Inadequate detailing and/or unsatisfactory construction practices at locations of potential moisture penetration.
Discussion: In general all roof penetrations and changes in levels are well detailed in terms of tolerances and materials at all schools. A notable and inconsistant exception is the circular skylight details at the Richards School in which upstand flashing is omitted and the roofing felts are not carried up the edge of the raised skylight. These omissions provided a direct path for moisture and extensive leakage and water staining occured inside the building. This may have been the major factor which caused total saturation and replacement of the roof a year after occupancy. This has been corrected. The valley flashing over the multipurpose room was incorrectly installed--the flashing was improperly soldered--and this too caused leakage and was corrected.

At Mt. Healthy flashing was improperly installed at the junction of a lower roof that meets an exterior wall and around skylight monitors. This is in the process of being corrected. In the first case, the lower Roof/Exterior wall detail, the exterior wall material was changed from that specified on the working drawings- from diagonal wood siding to brick. We have not seen any revised drawings and there is a possibility that this change was made without the care of the original set or that because the original building form was unaltered, that this form was not sympathetic to the new and unanticipated materials, thus causing problems.

MOISTURE PENETRATION/MOVEMENT (Figure B.8)

Results: Performance is satisfactory (95%) at all schools with the exception of Richards (below 75%) where structural movement has resulted in moisture penetration through the roof membrane.
Probable cause: Thermal expansion and contraction of the 54 foot trusses over the multipurpose room causes openings in the roofing membrane.
Discussion: Unusual circumstances must be present for this phenomenon to occur for the roofing membrane is flexible. At the Richards School we believe these exceptional circumstances did occur as a result of some rather complex relationships.

The 54 foot long roof trusses over the multipurpose room are not free to move at their ends. Since the school is not air-conditioned and the trusses are at the top of this high space they are subject to considerable thermal expansion (and contraction). As they expand and contract they push the exterior walls in and out. This exterior wall is, in turn, restrained at its midheight by the adjacent corridor structure and this joint between the lower (corridor) roof and this moving wall is constantly opening and closing. This is beyond the capacity of the membranes and flashing to absorb this movement leads to water leaking in. This condition exists in the corridors at every point where the lowest roof truss abuts the corridor wall.

It should also be noted (see exterior walls) that extensive cracking occurs on the multipurpose room side emanating from this lowest truss. This may be due to the weight of water in the valley above or to this restrained movement as the lower portion of the wall cannot move outward while the upper portions can.

We believe thermal expansion and contraction of the brick exterior wall of some classrooms has 'popped' the rivets holding sections of aluminum flashing together. Wind-driven water has penetrated the flashing at these points and run into the classroom staining the ceiling. This, however, may also have been caused by expansion of the flashing itself.

DETERIORATION

DETERIORATION/EROSION

Results: In general the roofs are weathering well with the exception of Mt. Healthy (85%) where erosion of aggregate is significant considering that the roof is only two years old. The Richards roof shows excessive deterioration (75-85%).
Probable cause: Unsatisfactory adhesion of the aggregate to bitumen roof membrane at Mt. Healthy. Poor construction seems to be a problem at Richards. A fire in one section of the school has also blistered the roof above it.
Discussion: The mineral aggregate on the roof surface is critical to the durability of the roofing system. It provides protection of the membrane from impact, infrared and ultraviolet light, to some extent minimized excess expansion and helps reduce blistering and alligatoring. The aggregate must be applied when the final layer of roofing bitumen is still hot so the aggregate is sufficiently bonded to this material.

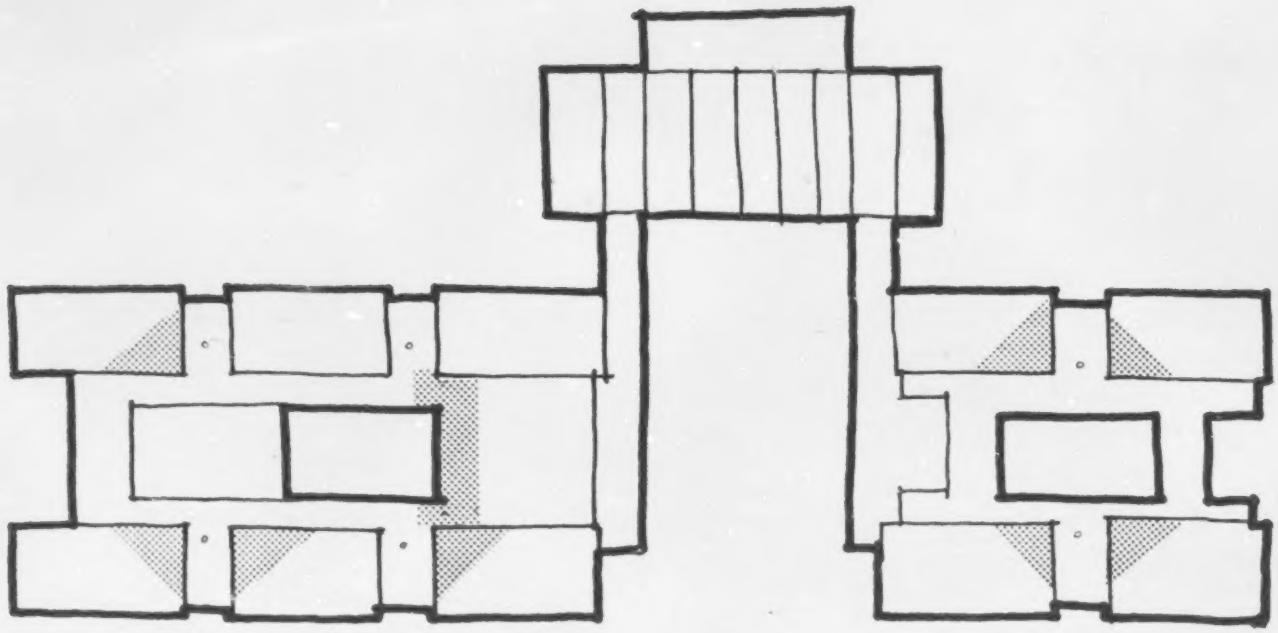
IMPACT/INDENTATION
BRITTLENESS

IMPACT/INDENTATION/BRITTLENESS

Results: Performance levels are satisfactory at all schools examined.

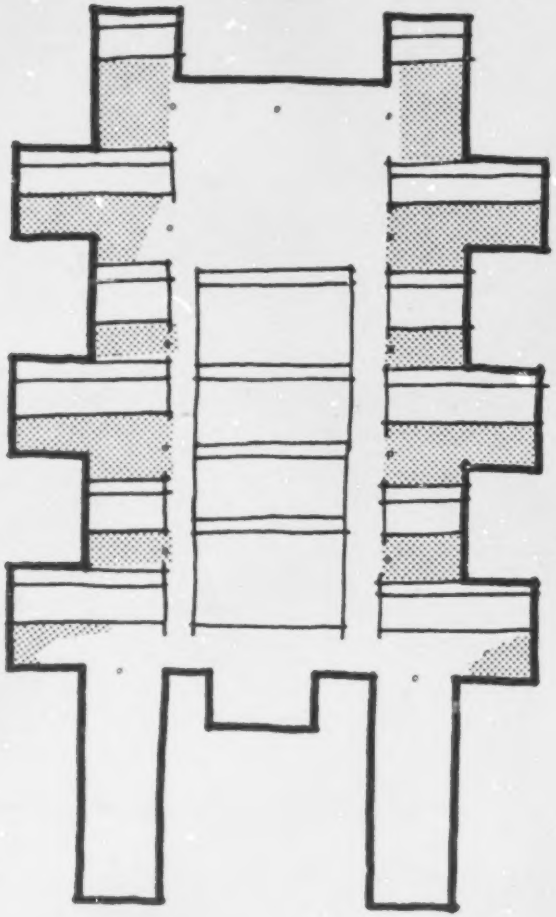
Probable cause: Not applicable

Discussion: The lack of impact and indentation problems to a large degree can be attributed to the fact that these roofs are only accessible to maintenance personnel. Most problems occur when roofs are used for activities or by hail impact. Brittleness is often caused by an inadequate final bitumen layer which by hastens the aging process of the bitumen. Neither impact or brittleness is a problem in these buildings.

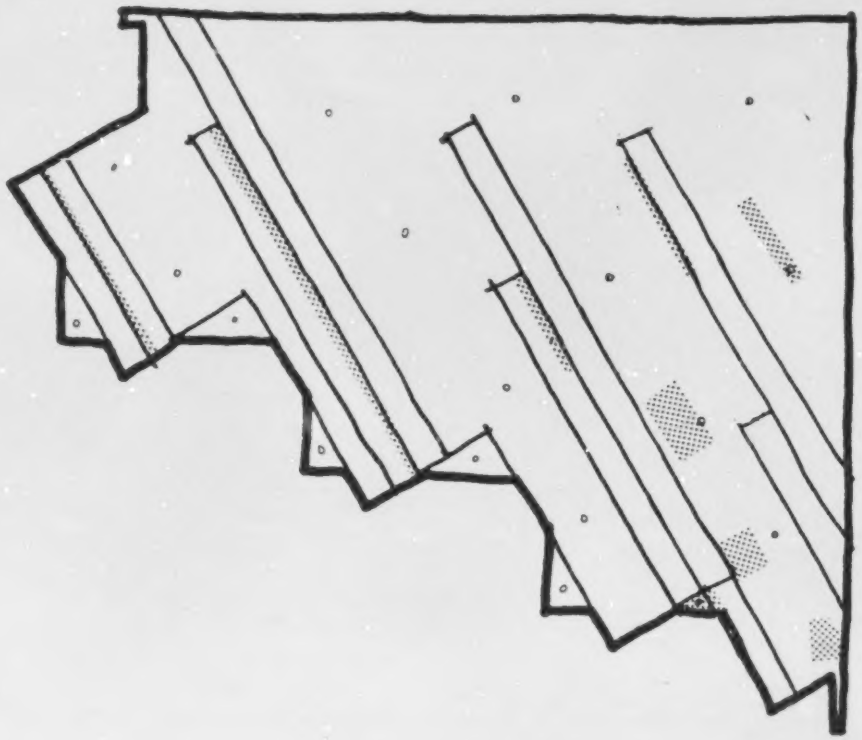


PARKSIDE SCHOOL: PONDING

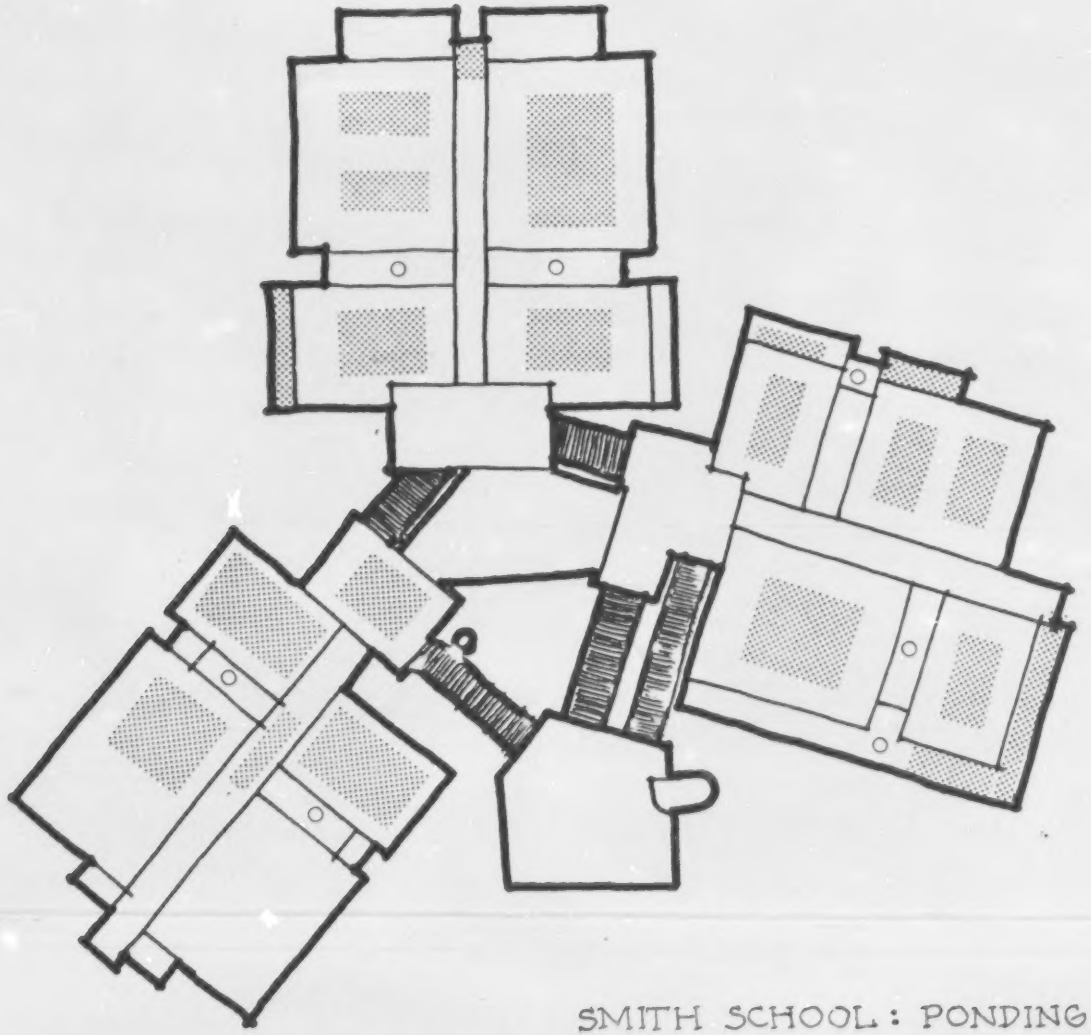
FIGURE B-1



RICHARDS SCHOOL: PONDING
FIGURE B.2

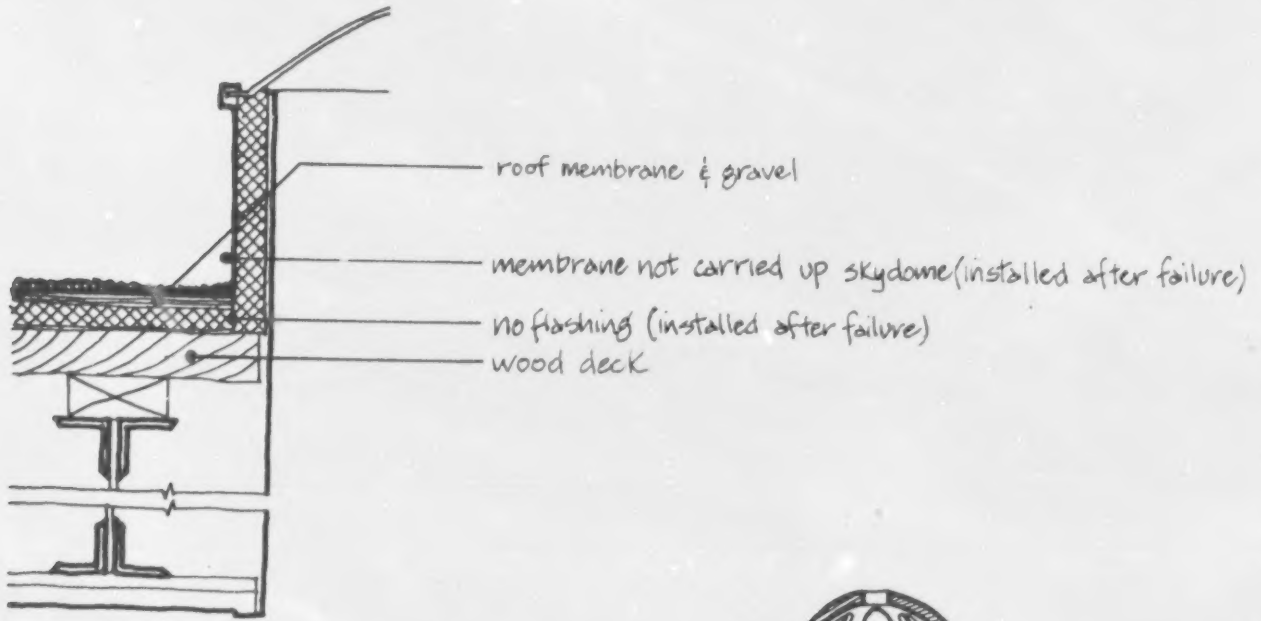


MT. HEALTHY SCHOOL: PONDING
FIGURE B.3

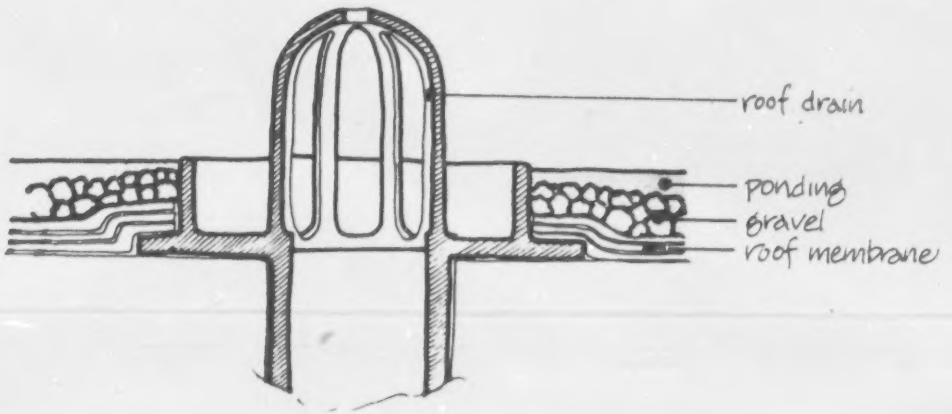


SMITH SCHOOL : PONDING

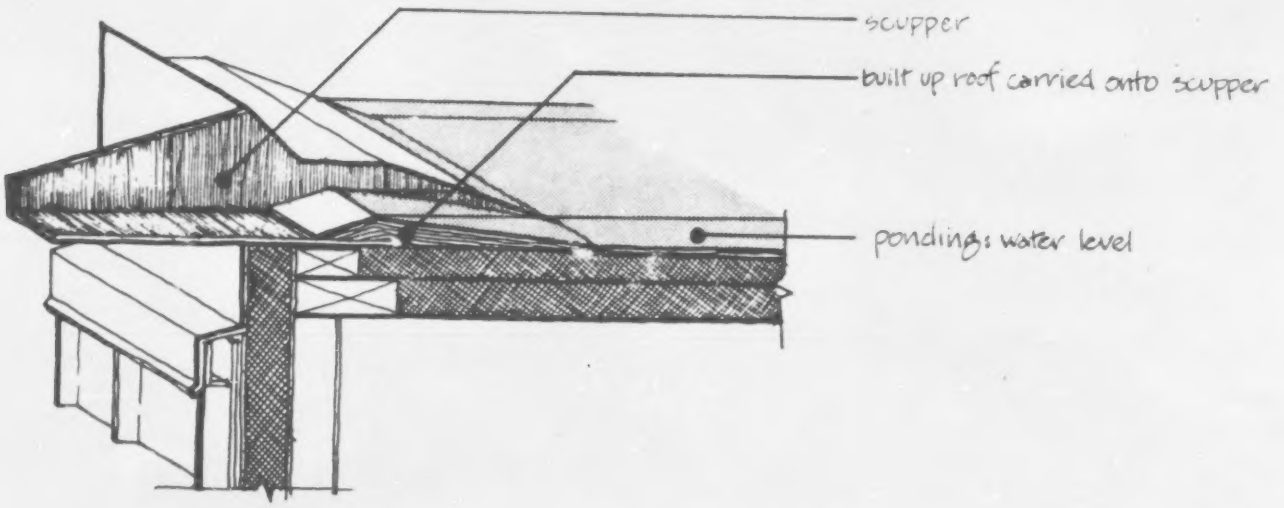
FIGURE B.4


roof membrane & gravel
membrane not carried up skydome (installed after failure)
no flashing (installed after failure)
wood deck

RICHARDS: SKYDOME
FIGURE B.5

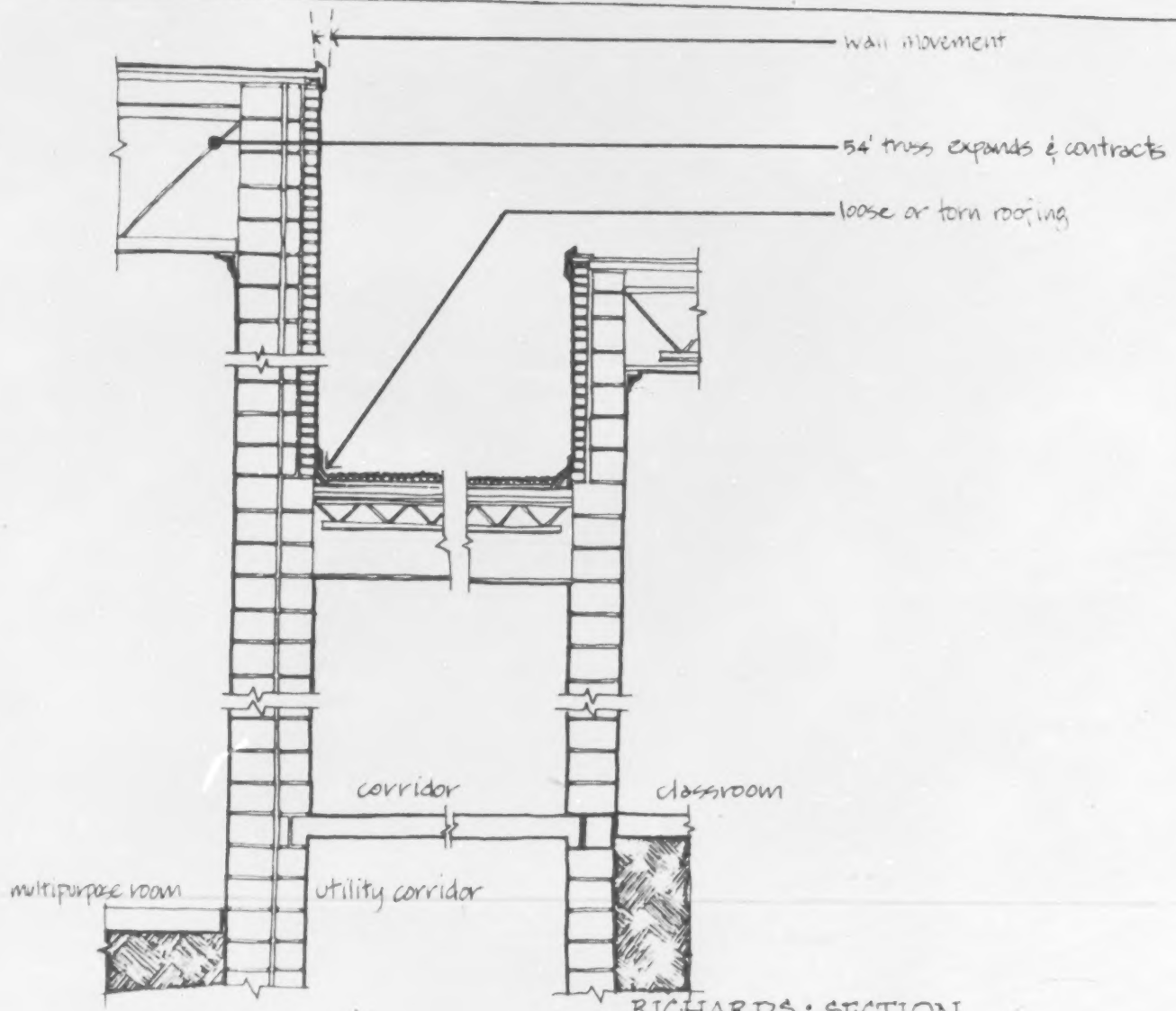


RICHARDS: ROOF DRAIN
FIGURE B.6



SMITH: SCUPPER

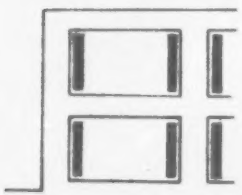
FIGURE B.7



RICHARDS : SECTION
FIGURE B.8

INTERIOR WALLS

INTRODUCTION



Many requirements affect the performance of the interior wall surface. Functional requirements of the enclosed space often require that equipment, furniture and other objects be attached to, hung from or abut the interior surface of the wall. As a membrane firmly attached to the load-bearing wall, it often displays tell-tale traces of undue movement before these are noticeable in any other part of the structure. Natural lighting and ventilation of the enclosed space, access to or egress from it, require openings of various dimensions and types, making its surface discontinuous. It must resist deterioration with age, and abuse as well as normal use. It must be maintainable and aesthetically pleasant. The extent to which these requirements are met will determine how well this subsystem performs. This subsystem, however, is not subject to the severe deterioration potential of exterior subsystems. Interior forces on the walls causing problems are rare and with routine maintenance this subsystem should perform well.

A variety of materials were used for the interior walls at the four schools studied, the most prevalant being painted concrete block. The exception is the Smith School in which gypsum wallboard mounted on metal studs was used.

This report concentrates on these predominant material types of such heavily-used areas as classrooms and corridors of each school. Limited application materials and less intensively-used areas of each school have been excluded, except where exceptional problems were encountered in their use.

METHOD OF EXAMINATION

A sample of classrooms, including more than 50% of each type and at least one from each grade level, was selected and studied in addition to the main common areas of the school and specialized areas such as the library, multi-purpose room, etc., thus ensuring a representative cross-section of room types.

Visual observation of the interior wall surface was the primary method of examination. Walls were examined for cracks, deflections and other indications of structural instability and attempts were made to correlate these findings with the location of expansion joints and known areas of exterior wall movement. The interior walls were also examined to determine if they provided sufficient support for attached loads.

Durability, water resistance, surface cohesion and general maintainability were checked by noting the type, extent and frequency of damage or change in the wall surface.

Equipment used to perform the tests: a four foot level to check for plumbness and deflection; a tape measure to determine the length of cracks; a small rule calibrated to 1/64 inch to measure the width and depth of cracks; various cleaning solutions to test staining and washability; and a camera used to record significant findings.

For a more detailed description of the testing procedures used refer to the Field Test Manual, 'Buildings In Use' Study, December, 1974

SUMMARY OF PERFORMANCE	P	R	S	M
GYPSUM WALLBOARD				
Structural Stability	NA	NA	O	O
Wearability	NA	NA	O	O
Delamination/Cohesion	NA	NA	O	O
Water Absorption/Stain Resistance/Cleanability	NA	NA	O	O
Repair/Aesthetics	NA	NA	O	O
CONCRETE BLOCK WALLS				
Structural Stability	O	O	NA	NA
Wearability	O	O	NA	NA
Adhesion	⊙	⊙	NA	NA
Water Absorption/ Stain Resistance	O	O	NA	NA
Cleanability	O	O	NA	NA
INTERIOR WOOD TRIM				
Wear/Repair/Aesthetics	⊙	⊙	NA	NA

SUMMARY OF FINDINGS

In no school examined was there any serious technical problem with the interior wall. Some specific minor cracking was found but they are in no way detrimental.

The performance of white paint was found unsatisfactory (75%) in some locations. It quickly soils, stains and shows surface flaws requiring more frequent maintenance.

Wood trim around doors and windows at the Parkside and Richards Schools showed signs of wear, chipping and abrasion, indicating that wood does not perform satisfactorily in these instances. instances.

The interior walls at Smith Elementary School were generally in good condition. Interior wall surfaces at Parkside and Mount Healthy were found to be performing satisfactorily, at the 95% level.

DETAILS OF FINDINGS

GYPSUM WALLBOARD

GYPSUM WALLBOARD: STRUCTURAL STABILITY

Results: Performance was satisfactory at the Smith School--the only school which typically uses this material, though some hairline cracking does exist, these instances are insignificant from a performance standpoint.
Probable cause: Not applicable
Discussion: Not applicable. Of purely academic interest is a hairline crack, hardly noticeable, above the midpoint of the classroom. This seems to indicate a slight deflection at this point.

GYPSUM WALLBOARD: IMPACT RESISTANCE, SUPPORT FOR ATTACHED LOADS, INDENTATION, WEARABILITY

Results: Performance levels were acceptable at the Smith School
Probable cause: Not applicable
Discussion: Not applicable

INTERIOR GYPSUM WALLBOARD: DELAMINATION, COHESION

Results: Performance levels were generally satisfactoy (95%). However, instances of surface delamination of the gypsum wallboard occur in classroom walls.
Probable cause: The use of adhesive tape to hang wall displays, posters, etc. Removal of such tape often pulls paint off with it.
Discussion: No wall area is designed specifically for display and thus existing gypsum walls are used for this purpose. For further discussion of this issue, refer to the Display section of the Functional Factors Report, "Buildings In Use' Study, March, 1974.

INTERIOR GYPSUM WALLBOARD: WATER ABSORPTION, STAIN RESISTANCE, CLEANABILITY

Results: Performance levels at the Smith School were very satisfactory.
Probable cause: Not applicable
Discussion: Not applicable

INTERIOR GYPSUM WALLBOARD: REPLACEMENT/REPAIR, AESTHETICS

Results: Performance was acceptable at the Smith School.
Probable cause: Not applicable
Discussion: Not applicable

CONCRETE BLOCK WALLS

CONCRETE BLOCK WALLS: STRUCTURAL STABILITY

Results: Performance levels were satisfactory (95%) at Parkside and Mount Healthy. Performance levels of the interior walls were only adequate (85%) at Richards due to specific occurances of cracking.
Probable cause: Thermal expansion and contraction, shrinkage and construction are all possible causes.
Discussion: The concrete block wall interior at Parkside and Mount Healthy were found to perform satisfactorily. Discussion of extensive cracking in the Richards School can be found in the exterior walls section (A-6).

CONCRETE BLOCK WALLS: IMPACT RESISTANCE, COHESION, DELAMINATION, WEARABILITY, INDENTATION

Results: Performance levels were very satisfactory (95%) in all schools using this material.
Probable cause: Not applicable
Discussion: Not applicable

CONCRETE BLOCK WALLS: ADHESION

Results: Performance levels were generally satisfactory (95%), however, difficulty is experienced in mounting posters and displays on the concrete block walls.
Probable cause: Concrete block resists adhesive tape because of its surface texture and typically glossy painted surface.
Discussion: For further discussion, refer to the Display Section, Functional Factors Report, 'Buildings In Use' Study, March, 1974.

CONCRETE BLOCK INTERIOR WALLS: WATER ABSORPTION, STAIN RESISTANCE

Results: Performance levels were satisfactory (85%) at the Richards School. Some visible water staining has occurred at Mount Healthy (85%).
Probable cause: interior of exterior wall was water stained, probably due to water infiltration.
Discussion: This seems to have been an isolated occurrence.

CONCRETE BLOCK INTERIOR WALLS: CLEANABILITY

Results: Performance was generally satisfactory (95%) at Parkside and Mount Healthy, but only adequate (85%) at Richards. A 'smudge' line between 2'-4' above floor level is easily

visible, especially in corridors. This line is lower in the lower grade corridor and higher in the upper grades.
Probable cause: Use of white paint on concrete block walls at Richards. Children's hands often run over this painted surface as they move through the halls.
Discussion: The use of white paint on both concrete block wall surfaces and wood trim, in that it soils and stains quickly and this requires more frequent cleaning and does not perform well in an elementary school. Brightly painted but darker colors between 1'-4' above the ground in the corridors would greatly improve this situation--reducing the frequency of cleaning and routine painting.

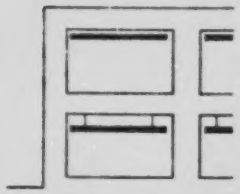
INTERIOR WOOD TRIM

INTERIOR WOOD TRIM: ABRASION, WEAR, REPAIRABILITY, AESTHETICS

Results: Performance of wood trim was only adequate (75-85%) at Parkside and Richards, showing signs of extensive wear, abrasion and chipping of paint. Performance was acceptable (95%) at Smith and Mount Healthy where metal trim was used.
Probable cause: Normal 'wear and tear' of an elementary school environment.
Discussion: The use of wood trim around classroom doors and windows (particularly on window sills as low as those at Parkside) was an inappropriate choice of material in such a high-intensity use facility as an elementary school. Parkside's oak trim is wearing better than Richards' white painted soft wood. The oak trim on the Parkside window sills is often stained because plants are placed upon them, leak, and oak stains readily when wetted. A clear plastic finish may prevent this occurrence.

CEILINGS

INTRODUCTION



Two generic types of exposed ceiling were examined in this study. The first is a relatively thin surface which is attached or hung from the structure. The second type forms the roof or floor deck besides acting as the finished ceiling.

While the ceiling has little direct relationship to classroom activities, it must be durable, maintainable and safe. Performance related to lighting and acoustics is included in sections F and G of this report. The extent to which the appropriate requirements are met determines how well this sybsystem performs. In general, this subsystem is less affected by outside forces than any other and its technical performance is usually high.

The ceiling of the Parkside School is primarily structural wood decking which is painted white. Richard's School on the other hand uses a finished white hung fiber acoustical ceiling which is not structural. The Smith School uses a thick aluminum pan ceiling finished on its exposed side which is also structural. This recently has had acoustical tile applied to it in many areas of the school. Mount Healthy uses an exposed structural fiber panel ceiling which acts as roof deck. It is unpainted on its exposed surface. Each type as described above is treated separately in the discussion of findings. Ceiling types with limited applications such as in kitchen and gymnasium areas are not included in this report.

METHOD OF EXAMINATION

Visual observation was the primary method of examination in all schools. Where further investigation was warranted, testing was performed. Equipment used was relatively simple: a level, tape measure and ruler graduated to 1/64 inch. A tension scale was used to test the stability and adhesion of the ceiling. A camera was

used to record significant results. A more detailed description of testing procedures used can be found in the Field Tests Manual, 'Buildings In Use' Study. December, 1974.

SUMMARY OF PERFORMANCE	P	R	S	M
WOOD DECK				
Replacement/Repair	O	NA	NA	NA
Out of System Hardware	O	NA	NA	NA
All other considerations	O	NA	NA	NA
ACOUSTICAL TILE				
Deflection/Displacement	NA	⊙	⊙	NA
Cohesion/Adhesion	NA	O	⊙	NA
Indent/Scratch/Stain	NA	⊙	O	NA
Color/Flaking/Fading	NA	⊙	O	NA
Replacement/Repair	NA	●	●	NA
RIGID FIBER PANELS				
Deflection/Displacement	O	NA	NA	O
Cohesion/Adhesion/ Indent/Scratch/Stain	O	NA	NA	⊙

SUMMARY OF FINDINGS

Performance levels of the various ceiling materials studied were very satisfactory (85-95% level). This subsystem is usually not affected by outside forces and thus its performance is typically at a high level.

The Parkside School ceiling had the best performance of any school examined. A close examination of the subsystem showed virtually no problems.

Serious problems occur at the Richards School and are caused by the leaking roof. Performance required by this subsystem does not include resistance to such undue causes and thus the lack of cohesion and the staining of this subsystem does not therefore constitute detrimental performance. However, while the aluminum pan ceiling at the Smith School performs well (85%), acoustical problems (see section G) have necessitated attachment of fiber acoustical tile to this aluminum ceiling in many areas.

At the Mount Healthy School, a relatively new facility, the ceiling has satisfactory performance (95%), though in some places it has been saturated by roof leakage it has retained stability and cohesiveness.

DETAILS OF FINDINGS

WOOD DECK

WOOD DECK/PARALLEL TO FLOOR, DEFLECTION AND DISPLACEMENT, COHESION, ADHESION, INDENTATION, SCRATCH, STAIN, COLOR HOMOGENITY, FLAKING, PEELING, DUST ACCUMULATION, CLEANABILITY

Results: Performance was satisfactory in all of the above attributes of the Parkside School ceiling.
Probable cause: Not applicable
Discussion: Not applicable

WOOD DECK/REPLACEMENT, REPAIR

Results: Some minor staining and deterioration is present (85%).
Probable cause: Rare incidents of water penetration through the roof.
Discussion: Previous incidents of leakage have occurred which have caused some problems with the ceiling which have not been repaired or repaired incorrectly. We feel these are not continuing problems and that performance is acceptable.

WOOD DECK/OUT OF SYSTEM HARDWARE

Results: Performance is satisfactory. Electrical conduit is exposed on the classroom ceilings.
Probable cause: No available plenum space
Discussion: The electrical conduit used to supply ceiling luminaries is exposed, however, this does not cause a reduced level of performance.

ACOUSTICAL TILE

ACOUSTICAL TILE/PARALLEL TO FLOOR, DEFLECTION, DISPLACEMENT

Results: Performance is unsatisfactory (75%) in a few areas of the Richards School. Ceiling tiles have become displaced.
Probable cause: The suspension system used makes replacing tile difficult.

Discussion: A 'Z' spline type of suspension system was used which does not allow the easy replacement of one or a few tiles because tiles and splines interlock on all sides. The ad hoc solution used-cutting the 'tongue groove' edge of a tile off and fitting in one tile-will usually loosen in time because of the tenuous fit and visibily 'tilt' in the ceiling. This is not judged harmful but usually is quite evident.

ACOUSTICAL TILE/COHESION, ADHESION

Results: Performance level marginally acceptable (75%) at the Smith School (replacement tiles) and acceptable at the Richards School (85%).
Probable Cause: Replacement tile is being adhesively applied to the ceiling of the Smith School to solve acoustical problems. In some instances the tiles are falling because the painted surface of the aluminum pan to which they are adhered is delaminating from the metal.

ACOUSTICAL TILE/INDENTATION, SCRATCH, STAIN

Results: Performance is satisfactory. Staining occurs at the Richards School.
Probable cause: The staining of the ceiling tile is due to extensive leakage through the roof carrying dirt and rust.
Discussion: The water penetration through the roof membrane, which is described in more detail in the roof section of this report, has caused extensive damage to the ceiling. Attributes of this subsystem do not include resistance to such undue incidents and thus have been rated satisfactory. Tiles have been replaced (11-'74).

ACOUSTICAL TILE/COLOR HOMGENEITY, FLAKING, FADING

Results: Performance was satisfactory (85-95%) for these attributes.
Probable cause: Not applicable
Discussion: Not applicable

ACOUSTICAL TILE/REPLACEMENT, REPAIR

Results: Performance in the attribute of replacement is unsatisfactory (below 75%) at the Richards School.
Probable cause: The suspension system creates problems in replacing ceiling tile and the future performance of that tile.
Discussion: A "Z" spline ceiling system which uses 'z' shaped splines 12" on center to which the ceiling tiles are attached and the spline system is not visible is used. Due to the nature of this system it is extremely difficult to replace a single ceiling tile.

RIGID FIBER PANELS

RIGID FIBER PANELS/DEFLECTION, DISPLACEMENT

Results: Performance was satisfactory at the Mt. Healthy School.
Probable cause: Not applicable
Discussion: Not applicable

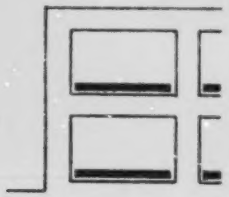
RIGID FIBER PANELS/COHESION, ADHESION, IDENTATION, SCRATCH, STAIN

Results: The performance at the Mount Healthy School was satisfactory. Cohesion performance of panels subject to water penetration through the roof membrane has been good.

Probable cause: Water penetration through the roof membrane has caused staining in some locations.
Discussion: The staining is only visible if the ceiling is inspected closely. The color of the panels (brown) and their textured pattern effectively camouflages existing staining.

FLOORS

INTRODUCTION



The finished floor is a membrane attached to the surface of the floor or subfloor which provides a surface suitable for use by the occupants of the facility. It is the only subsystem with which there is universal and continuous contact by user as well as by fixed and movable furnishings and equipment.

The primary concern of this subsystem is durability throughout its useful life: unattached objects naturally gravitate to it, often with considerable impact; it bears heavy static loads of long duration and it must resist the abrasive action of user circulation; it must withstand the effects of high strength chemical agents and possible deteriorating effects emanating from the structural subfloor on which it rests; in addition to these required qualities of durability it should not inhibit activities which occur on it while remaining easily maintainable and aesthetically pleasing. The extent to which these requirements are met determines how well this subsystem performs.

Three materials were primarily used on the four schools studied: finished concrete with a poured plastic composition flooring, resilient tile and carpeting. Limited use applications such as quarry tile in kitchen areas and wood gymnasium floors are not included in this study.

METHOD OF EXAMINATION

Visual observation was the primary method of examination in all schools. Appropriate field tests in the areas of staining, slip resistance and scratch resistance were used. The equipment used to perform field tests was simple: a level, tape measure and small ruler graduated in 65ths of an inch. Cleaning and staining soulutions were used where appropriate as was slip resistance apparatus. A camera was used to record examples of problems. For a more detailed description of the testing procedures used refer to the Field Tests Manual, 'Buildings In Use' Study, December 1974.

SUMMARY OF PERFORMANCE

	P	R	S	M
RESILIENT TILE				
Indentation/Impact	O	⊙	NA	NA
Resiliency	O	O	NA	NA
Brittleness/Cohesion/ Adhesion	O	O	NA	NA
Scratch/Wear	O	O	NA	NA
Slip Resistance	O	O	NA	NA
Cleanability/Dust	O	O	NA	NA
Water Absorption/ Delamination	O	O	NA	NA
Replacement/Repair	⊙	O	NA	NA
Cigarette Burn/Color	O	O	NA	NA

	P	R	S	M
CARPETING				
Indentation/Impact/ Resiliency	NA	NA	O	O
Adhesion	NA	NA	O	●
Wear	NA	NA	⊙	⊙
Static Discharge	NA	NA	O	O
Cleanability/Dust	NA	NA	O	O
Water Absorption/Stain/ Color Fastness	NA	NA	O	O
COMPOSITION FLOORING				
All Attributes	NA	NA	O	NA

SUMMARY OF FINDINGS

Performance levels of the various flooring materials used in each of the four schools studied was generally satisfactory with most functioning at the 85% performance level in terms of the overall characteristics of durability, maintainability and appearance.

A few instances of minor deterioration of the resilient tile flooring were found. Replacement tiles at Parkside do not match the original color and pattern.

The performance of carpeting in the area of durability was satisfactory (85%) with the exception of specific highly-trafficked locations. Some instances of fading, staining and seam tearing occurred at the Smith School (75%). The carpeting at Mt. Healthy, a relatively new facility was in superior condition (95%) with some minor wear problems. Advances in carpeting materials in the last 10 years may make a significant difference in performance. Recently installed carpeting is very superior in performance to earlier products.

DETAILS OF FINDINGS

RESILIENT TILE

RESILIENT TILE/INDENTATION, IMPACT

Results: Performance levels were satisfactory at the Parkside School (85%). Some instances of minor permanent indentation is present in the Richards School classrooms, with the resilient tile performing at the 85% level.
Probable cause: Long term static loads (e.g., table legs) have caused depressions in the floor tile at the Richards School. Short term static loads cause no permanent set.
Discussion: Resistance to long term loading is a key performance specification for resilient floor tile. At Richards, the tile used did not perform to required levels although in other respects it is performing well. Indentations found were in the 1/32"-1/64" range and visible from 5'. While this is not detrimental to activities or safety, it will probably tend to shorten the useful life of this finished floor.

RESILIENT TILE/RESILIENCY

Results: Performance levels were satisfactory at all schools.
Probable cause: Not applicable.
Discussion: Not applicable.

RESILIENT TILE/BRITTLENESS, COHESION, ADHESION

Results: Performance, in regard to brittleness, was acceptable (85% level) at Parkside and at Richards with specific instances of very minor problems. Performance, in regard to cohesion and adhesion, was satisfactory (95% level) at all schools.
Probable cause: Cracking due to tile bending over openings in the subsurface.
Discussion: Resilient tile is brittle and must not be subjected to excess bending. At two locations in the Richards School the tile has been subjected to bending and, as a result, has

cracked. One such location is the lower end of a ramped surface; the other is at the exterior wall. This latter condition is due to a portion of the tile resting on packed exterior wall insulation which is not able to support it.

At Parkside, resilient tile has cracked at expansion joints in the concrete subfloor which occur at the entrances to the classrooms. All of the instances at both schools are minor, being either too small to affect safety or in locations which do not bear traffic. It should be noted that these minor conditions often occur because of constructional procedures and their effect on the subsurface.

RESILIENT TILE/SCRATCH, WEAR

Results: Performance was acceptable at Parkside. A somewhat lower level of performance was judged to be found at Richards.
Probable cause: Unknown
Discussion: This is difficult to measure and in fact may be due to the color and pattern and not to actual 'in use' performance. However, the indentation found at Richards and not at Parkside (though Parkside is 4 years older) makes the Richards tile suspect as being somewhat 'softer'.

RESILIENT TILE/SLIP RESISTANCE

Results: Performance levels are satisfactory (85%) at the schools examined.
Probable cause: Not applicable.
Discussion: Not applicable.

RESILIENT TILE/CLEANABILITY, DUST ACCUMULATION

Results: Performance was very satisfactory (95% level) at both schools examined.
Probable cause: Not applicable.

RESILIENT TILE/WATER ABSORPTION, DELAMINATION

Results: Performance was very satisfactory (95% level) at both schools studied in these areas.
Probable cause: Not applicable.
Discussion: No evidence of damage due to water absorption was discovered, even in areas most susceptable. A waxed surface is used, and most liquids cannot penetrate such a surface.

RESILIENT TILE/REPLACEMENT, REPAIR

Results: Performance was satisfactory at Richards (95% level) but unacceptable (75% level) at Parkside.
Probable cause: An adequate supply of the original tile was not furnished for replacement and repair.
Discussion: The original tile pattern and thickness is no longer available. Although the need for replacements has been limited, they are evident because of the pattern and color differences (2 thicknesses of tile are used to make up the difference in depth). This has only an aesthetic effect, however, and is in no way detrimental to technical performance. An adequate supply of replacement tile (5-10% extra) should be available for the useful life of the floor.

RESILIENT TILE/CIGARETTE BURN, COLOR FASTNESS, COLOR HOMOGENEITY

Results: Performance was at a very high level (95%) in both schools.
Probable cause: Not applicable.
Discussion: Smoking is not allowed in either school. The tiles used were homogeneous and do not show wear easily. Color fastness, even in areas exposed to direct sunlight, is satisfactory.

CARPETING

CARPETING/INDENTATION, IMPACT, RESILIENCY

Results: Performance levels were acceptable (95%) at the Smith and Mount Healthy Schools.
Probable cause: Not applicable.
Discussion: Not applicable.

CARPETING/ADHESION

Results: Performance was satisfactory at Mount Healthy (95%). At Smith, classroom carpeting is unravelling at its seams (75%) in a significant number of instances.
Probable cause: Result of improper installation.
Discussion: Carpet seams are taped, rather than sewn, and in a few locations have torn loose. Wide bands of tape have been used to cover the ravelling and prevent further damage and this is readily apparant. This condition should be corrected.

CARPETING/WEAR

Results: Performance levels are adequate at Mount Healthy and in the classrooms at Smith (85%). Carpeting on the ramps is wearing excessively at Smith (below 75%). Carpeting on the nosings in highly trafficked stairs is showing wear at Mount Healthy after only 2 years.
Probable cause: A type of carpeting (indoor-outdoor) was specified which does not withstand the intense usage in the corridors. Nosings of stairs get very high wear.
Discussion: After some 7 years of intensive use, the carpeting at the Smith School shows excessive wear and will soon need to be replaced. The wear on the nosings of the Mount Healthy stairs is considerable taking into account the short period of use (2 years) but not unexpected. This area carpeting will need to be replaced considerably before the rest of the building's carpeting. Whether any carpeting will wear well on the nosing should be investigated. Carpeting on the 'big steps' at Mount Healthy is wearing well; however, the nosings on the ends of the steps which attracts most traffic shows early signs of wear and will need to be replaced before the rest of the carpeting.

CARPETING/STATIC DISCHARGE

Results: Performance levels were satisfactory at Mount Health and unsatisfactory (below 75% performance) at Smith.
Probable cause: Accumulation of static electricity through walking. Discharge to metal.
Discussion: Nylon, the material specified for the Smith School carpet is one of the worst in terms of static discharge performance. This may not be a problem if humidity control (above 60%) were present; however, the HVAC system does not provide this control.

CARPETING/CLEANABILITY, DUST ACCUMULATION

Results: Performance was satisfactory at all schools using carpeting.
Probable cause: Not applicable
Discussion: Minute particles retained by carpeting are a source of excessive wear. No evidence of such problem exists in the shcools studied probably due to the adequacy of the routine maintenance.

CARPETING/WATER ABSORBANCY, COLOR FASTNESS, STAIN

Results: Performance was generally satisfactory at the Smith and Mt. Healthy Schools. Any failures found are caused by undue outside forces. Some isolated fading is present at the Smith School.
Probable cause: Water penetration at the Mt. Healthy School has caused failure of the carpeting in one area. This carpeting has already been removed and was not examined in this project. Excessive staining of the ramp carpeting has occurred at the Smith School due to undue water penetration at the lower end of the sloped ramps. Color fading at the Smith School is very minor.
Discussion: The staining and the water absorbancy occurrences are the result of unusual and undue forces which this flooring is not made to resist. In terms of normally expected performance, especially in areas of potential problems (e.g., around classroom sinks) carpeting performed at quite satisfactory levels. For instance, carpeting below the cafeteria counter at Mount Healthy showed little staining. This most vulnerable spot indicates a high level of performance. The dark colors used and the presence of pattern also give positive effects in this area.

COMPOSITION FLOORING

COMPOSITION FLOORING/ALL ATTRIBUTES

Results: Performance was satisfactory for all characteristics of this material which was used in the heavily trafficked nodule areas of the Smith School. It is wearing very well and is well maintained. This is a clear finish and does show imperfections in the concrete structural floor.
Probable cause: Not applicable.
Discussion: The uneven coloring of the floor due to the finish of the structural floor below is consistant with the architect's intention in the design of a 'brutalist' building.

ACOUSTICS

INTRODUCTION

The acoustical environment of a space is a product of the physical geometry of that space, the acoustical properties of the materials of which it is constructed, and of the type and intensity of use.

At any time of day a typical elementary school contains areas which are quiet and areas of intense activity. In any area or room there is the potential to generate more noise than the activity, as well as, adjacent occupancies, can accept. It is important that classrooms and other areas be essentially sound absorptive, rather than sound reflective, so that diverse activities can occur simultaneously witout mutual interference.

An enclosed space has three primary characteristics which determine the quality of the acoustical environment. These are:

- Ambient sound level, which measures the amount of existing background noise;
- Reverberation time, which measures the tendency of sound to 'dwell' in the space (its decay time); and
- Attenuation, which indicates the loss of intensity of sound transmitted over distance or through a wall.

Determining, by direct measurement, the behavior of individual spaces within each of the schools in regard to these three criteria and comparison with accepted standards of acoustical performance results in an indication of the acoustical quality of the school environment.

METHOD OF EXAMINATION

Two methods of acoustical examination were used in this study. Ambient noise and attenuation tests were performed in the classrooms and corridors primarily using a Bruel & Kjaer Type 2203 precision sound level meter equiped with a Type 1613 octave band analyzer. White noise for determining sound transmission was provided on a pre-recorded casette tape. These measurements provided a basis for analytic comparisons of classroom acoustics and the transmission characteristics of the interior walls, both within and between the various schools, to accepted standards.

Bolt, Beranek and Newman, Inc., was retained to measure and analyze reverberation time, particularly of spaces in excess of 2000 square feet.

The results of these testing procedures are presented in graph form in the following section, Detailed Findings. For a more detailed descritpion of the testing procedures used, refer to the Field Tests Manual, 'Buildings In Use' Study. December, 1974.

SUMMARY OF PERFORMANCE	P	R	S	M
AMBIENT NOISE				
Unoccupied Classroom	○	○	○	○
Unoccupied Large Spaces	○	○	○	⊙
Occupied Classroom	○	○	○	○
Occupied Large Spaces	⊙	⊖	○	○
Lighting and Mechanical Equipment	⊙	○	○	⊙
TRANSMISSION				
Between Classrooms	⊙	○	○	NA
Hallway/Classrooms	⊙	⊙	⊙	NA
Multipurpose Room/ Classroom	NA	⊙	NA	NA
REVERBERATION				
Classroom	○	○	○	○
Large Spaces	●	●	⊙	○

SUMMARY OF FINDINGS

LEARNING AREAS (UNDER 2000 SQ.FT.)

Classroom acoustics in all the schools is almost entirely adequate. Ambient sound levels are loud enough to provide 'masking' of minor noises and low enough to prevent interference with learning activities. Room-to-room sound isolation is satisfactory, although one school does have a somewhat lower level of performance. Sound isolation between the hallway and classrooms was found to be only marginally adequate (75-85%), however.

At Richards school, a centralized multi-purpose room and the high sound levels generated there does interfere with adjacent classrooms which, because of their curricular needs, tend to leave their doors open. In the other schools the multi-purpose/gym is not adjacent to classrooms.

High reverberation times were found in the large, double (30 ft. x 60 ft.) Smith classrooms due to a 'hard' metal pan ceiling, the carpeting on the floor notwithstanding. That ceiling has since been replaced by acoustically-absorbant ceiling tiles which have reduced reverberation to within acceptable limits. Smith's smaller classrooms have the original metal pan ceilings and reverberation times there are somewhat higher than at the other schools, although still within acceptable limits. At the Parkside School the mechnical noise (ballasts) were judged too noisy in classroom areas.

LARGE AREAS (OVER 2000 SQ.FT.)

Room-to-room transmission is the only area of adequate performance for large activity areas.

High ambient noise and high reverberation times are present in almost all large spaces, primarily because of inadequate sound absorption. The Richards and Parkside multi-purpose rooms have the greatest problems because:

a) acoustical inadequacies, in terms of ambient noise and reverberation time, are much more pronounced than at the other schools; and

b) both spaces concerned being multi-purpose spaces, a variety of activities with a wide range of acoustical requirements are programmed to occur in them. Alternate spaces do not exist.

The above problem also exists at the Smith and Mount Healthy Schools. However, because the inadequacies of the acoustical environments are less pronounced and because other areas of these schools can be programmed for assemblies, meetings, drama, etc., the effects of these inadequacies are minimized and performance is more acceptable because the criteria are not so strict.

DETAILS OF FINDINGS

AMBIENT NOISE

AMBIENT NOISE/UNOCCUPIED CLASSROOM

Results: Ambient noise within acceptable limits (NC 35+ 5 db for traditional classrooms, NC 45+ 5 db for open classrooms).
Probable cause: Not applicable.
Discussion: Ambient noise levels should neither be too high, causing noise which interferes with clear hearing, not too quiet, an environment in which you can hear 'a pin drop'. Mechanical systems and lighting equipment provide most of this ambient 'background' noise level.

AMBIENT NOISE/UNOCCUPIED LARGE SPACES

Results: On the whole, large spaces fall within acceptable limits with the exception of the gymnasium at the Mount Healthy School where noise levels exceeded 62-63 DBA (75-85% performance).
Probable cause: Very loud ceiling mounted HVAC equipment within the space.
Discussion: Notwithstanding that this area is used only for gym-type activities, the background noise created by the mechanical equipment is above acceptable levels, making communication difficult even for such typically loud activities as gym classes.

AMBIENT NOISE/OCCUPIED CLASSROOM

Results: Within acceptable limits
Probable cause: Not applicable

Discussion: At the Mount Healthy School, the higher ambient noise levels reflect the children's activities added to the background ambient noise levels. An open classroom building, such as Mount Healthy, requires more 'masking' noise than a traditional school. The carpeting and exposed mineral fiber ceiling provides the absorption necessary to prevent unacceptable noise levels.

AMBIENT NOISE/OCCUPIED LARGE SPACES

Results: Satisfactory at Smith and Mount Healthy (85% performance). Occupied ambient noise levels at Parkside and Richards are much too high, especially during lunch-time and physical education activities (below 75% performance level).
Probable cause: Lack of absorptive surface materials.
Discussion: Originally built without absorptive materials, the gymnasium at the Smith School was extensively resurfaced with acoustical tile a year prior to this study, apparently with good results. The ambient noise levels reached at the unimproved older schools (Parkside and Richards) severely affect communication and other activities in the same area. The peak ambient noise levels found in the multi-purpose rooms of these two schools, 90-100+ dbA, are severe enough to cause severe discomfort, and even pain. Other problems also occur because of this lack of absorptive surface.

AMBIENT NOISE/LIGHTING AND MECHANICAL EQUIPMENT

Results: Satisfactory in all schools except Parkside where increases in ambient levels in a few classrooms (3-6 dbA resulting in approximately 40 dbA) do interfere with normal classroom communication (75-85% performance). Frequency of this distinct humming is in the normal speech range.

Probable cause: Loud humming lighting ballasts cause this increase in ambient levels.
Discussion: The flourescent ballasts were either specified incorrectly to begin with or have deteriorated in performance with age. The latter reason is most likely - the ballasts are 13 years old.

While the sound levels produced are not detrimental at these levels (approximately 40 dbA unoccupied) it is necessary to 'talk over' this background noise which is rather distinct. While it is an unconscious and easily made adaptation, is not the preferred condition.

TRANSMISSION

TRANSMISSION/BETWEEN CLASSROOMS

Results: Transmission of sounds between classrooms is within acceptable limits in all schools.
Probable cause: Not applicable.
Discussion: While attenuation between classrooms is lower at Parkside due to acoustical 'leaking' at the laminated beams, this transmission between spaces does not cause any difficulty in classroom situations. The transmitted sound is 'masked' by existing occupied ambient noise. Mount Healthy, with no walls between 'classrooms', was excluded from this test.

Note: The extension of the block partition above the hung ceiling at the Richards School was quite effective in reducing transmission through the ceiling cavity.

TRANSMISSION/HALLWAY/CLASSROOMS

Results: In the three schools studied which have partitions between hallway and classrooms, performance was found to be marginally adequate (75-85%). Sound is definitely transmitted to the classroom from the hallway (6-12 dbA at ambient level).
Probable cause: In each case an open grillwork is provided for return air from classrooms to centralized return grills in the corridors.
Discussion: Not an unexpected result under these design conditions. A direct path exists between source and receiver room. The traditional nature of the schools, where interference from the corridors is not expected adds to this problem. However, since corridors contain few or no 'activities' the situation is ameliorated.

TRANSMISSION/MULTIPURPOSE ROOM/CLASSROOM

Results: Richards School. Excessive transmission between the multi-purpose room and adjacent classrooms, notwithstanding the corridor between them.
Probable cause: Centralized location of the multi-purpose room proximate to the classrooms with intensive use generating high ambient noise levels in the multi-purpose room with little sound absorption. Curricular needs require doors between the multi-purpose room and the classrooms remain open to their mutual corridor.
Discussion: This problem is inherent in the concept of the centralized multi-purpose room used at Parkside. Careful acoustical treatment is necessary to prevent and correct this problem.

REVERBERATION

REVERBERATION/CLASSROOM

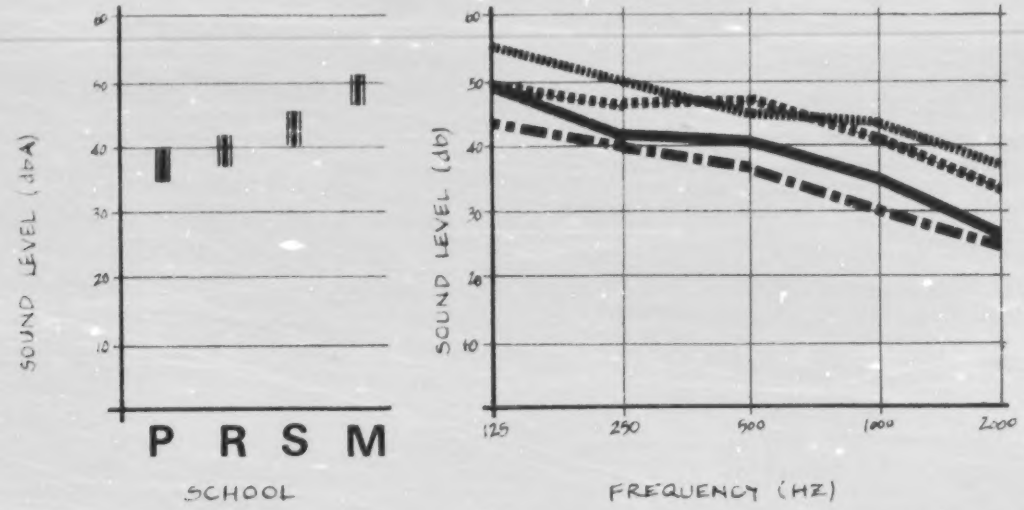
Results: Reverberation is within acceptable limits in all classrooms.
Probable cause: Not applicable.
Discussion: Just prior to the beginning of our study, the six double classrooms at the Smith School had their metal pan ceilings covered with acoustical tile. Based on the existing conditions and considering the previous ceiling finish--exposed metal pans--the original reverberation time would have been in excess of recommended standards. Significantly, in the single classroom at Richards which has not had such tile installed, the reverberation time borders on the limit of acceptability.

REVERBERATION/LARGE SPACES

Results: Severe problems in the Parkside and Richards multi-purpose rooms. Previously severe problem at Smith has been corrected. Acceptable conditions at Mount Healthy.
Probable cause: Large volume rooms (80,000 cubic feet) with hard surfaces and a lack of acoustically-absorptive materials.
Discussion: Reverberation time varies directly with the volume and indirectly with the amount of acoustically-absorptive material present. Therefore, large spaces with acoustically 'hard' surfaces have the greatest potential for problems in this area. The Parkside and Richards Schools have virtually no absorption in their large multi-purpose areas and, consequently, very severe reverberation problems. This is affirmed in the responses to a questionnaire given the teachers in both schools. Acoustical problems are so severe as to render these spaces useless for lectures, dramatics and other presentations.

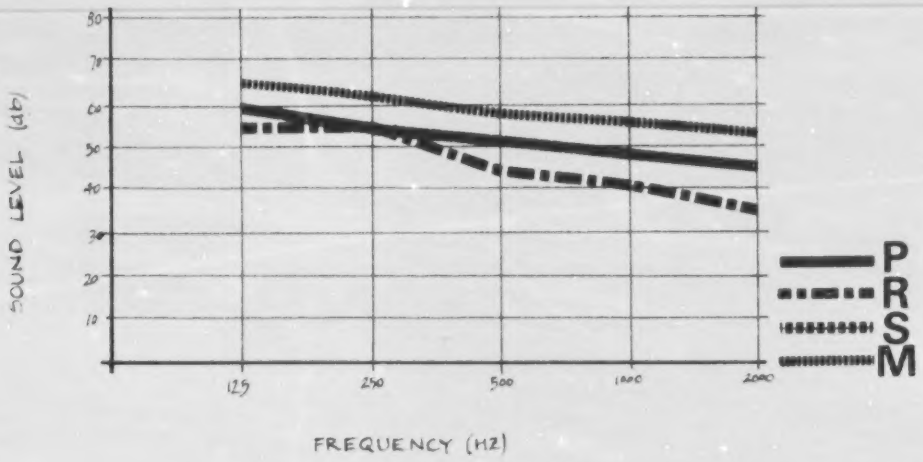
The multi-purpose room at Smith had extensive acoustical treatment prior to the beginning of this study, and present reverberation time is satisfactory although we are most certain this was not the case previously. Mount Healthy's gymnasium, with an exposed mineral tile ceiling, does have enough absorption to provide adequate performance.

F.1 AMBIENT SOUND LEVELS/UNOCCUPIED CLASSROOMS

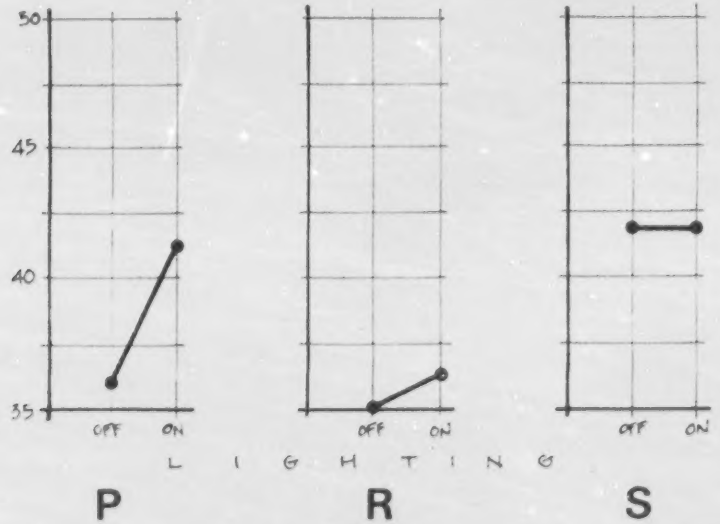


F.2 AMBIENT SOUND LEVELS/OCCUPIED SPACES

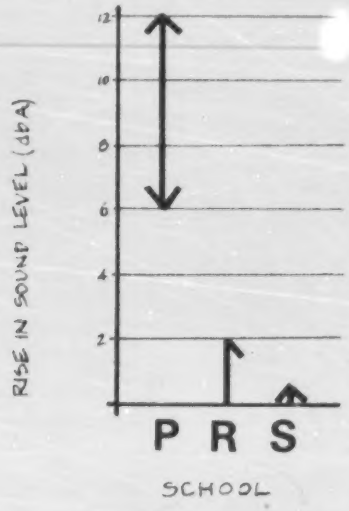
F.3 AMBIENT SOUND LEVELS/GYMS-MULTIPURPOSE ROOMS/UNOCCUPIED

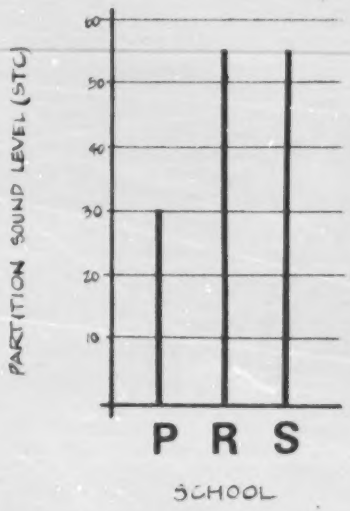


F.4 AMBIENT SOUND LEVELS/LIGHTING BALLAST

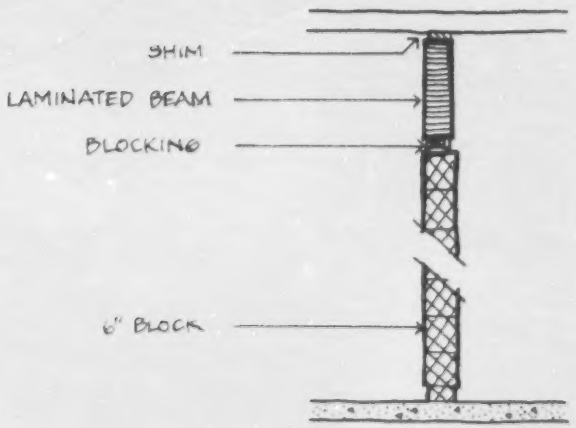


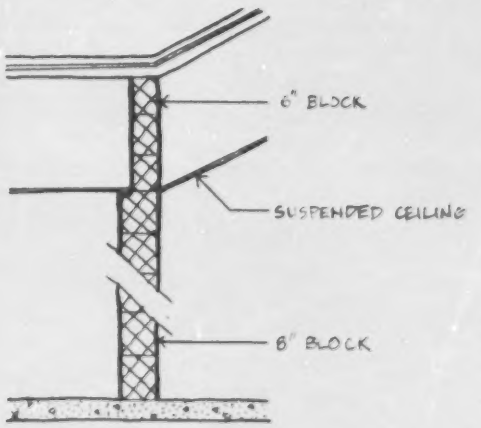
F.5 TRANSMISSION BETWEEN CLASSROOMS



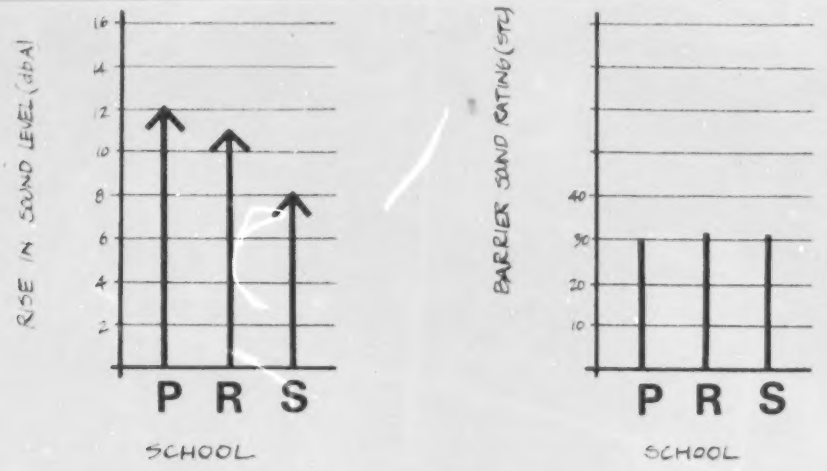


F.6 WALLS BETWEEN CLASSROOMS/SECTION

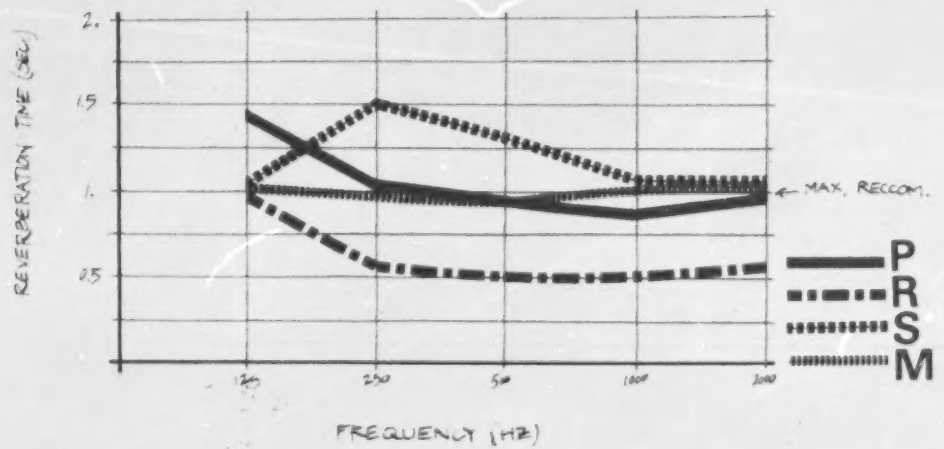




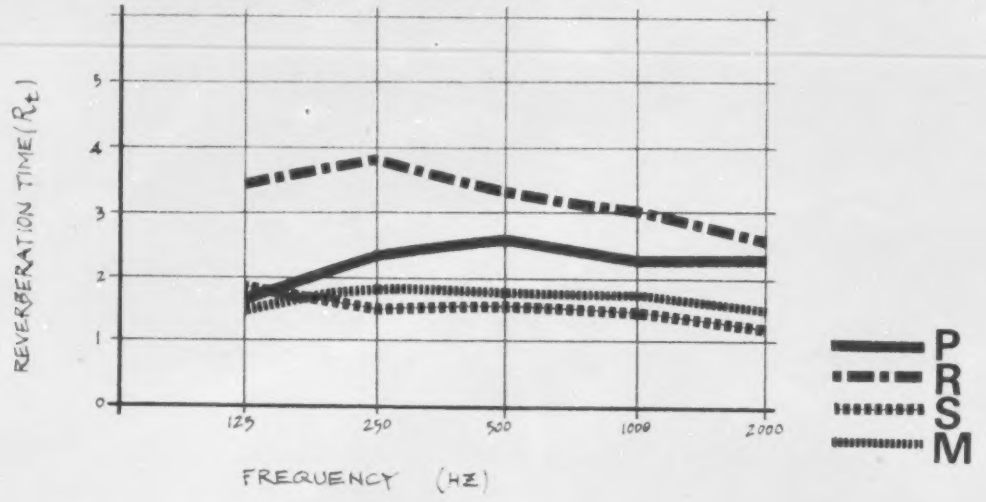
F.7 TRANSMISSION: HALLWAY/ CLASSROOM



F.8 REVERBERATION/CLASSROOMS



F.9 REVERBERATION : GYMS/MULTIPURPOSE ROOMS



LIGHTING

INTRODUCTION

Artificial and natural lighting provide the visual environment necessary for typical classroom activities. The performance of this visual environment is determined by a number of factors acting together: the quantity of light, the type of task, room brightness ratios, direct and reflected glare, and contrast rendition of the task surface. The quantity of illumination, which is the most common measure, alone is not a valid measure of lighting quality. In fact, improperly designed, a higher quantity of light can have a detrimental, rather than a beneficial, effect on occupants.

Unlike other technical factors included in our study which produce easily-recognizable and sometimes severe problems, improper lighting design produces eye strain, fatigue and discomfort which would be easily noticeable and attributable only under the most extreme conditions. The more subtle effects are difficult to pinpoint, but nonetheless affect the user.

Our criteria for good lighting design are taken from sources which include all the above mentioned factors and which should eliminate adverse physiological effects. Determining the performance of each of these characteristics and comparing these with recommended standards should produce a good indication of the quality, as well as the quantity, of lighting in the existing classrooms environments.

METHOD OF EXAMINATION

Measurements of the quantity of light (in classroom areas, only) were made with a General Electric Type 213 Light (foot-candle) Meter. Other measurements requiring luminance (foot-lamberts) readings were performed with Minolta and Honeywell (1°) spot meters. Measurements were made during different weather conditions and with the window shades in different positions. For a detailed description of the testing procedures used, refer to the Field Tests Manual, 'Buildings In Use' Study, December, 1974.

SUMMARY OF PERFORMANCE

	P	R	S	M
LIGHTING				
Illumination	○	⊙	○	⊙
Room Contrast Ratios	●	⊙	●	○
Glare	●	⊙	●	○
Task/Immediate Surround Contrast Ratios	○	○	○	○
Darkened Room	●	○	○	○

SUMMARY OF FINDINGS

The visual environments of the classrooms in all schools were entirely satisfactory in terms of the quantity of light present. However, in those schools whose classrooms had large window areas, such as Parkside and Smith, performance in the areas of room contrast rations and direct glare was not acceptable, generally functioning at below the 75% level. The Mount Healthy School, depending heavily on artifical illumination with windows used primarily for visual relief and high lighting, had the most satisfactory lighting environment with performance generally at the 95% level. The Richards School, which had smaller windows in each classroom and used large skylights, was also acceptable, functioning at the 85% level.

DETAILS OF FINDINGS

LIGHTING/ILLUMINATION (FOOTCANDLES)

Results: Performance levels with regard to the quantity of illumination were satisfactory at all schools examined. Some exceptional conditions exist at the Mount Healthy School which make technical performance evaluation difficult. Richards had lower illumination than recommended standards (85% level).
Probable cause: Existing criteria in the technical literature are based on traditional classrooms, and Mount Healthy is a radical departure from that model. At the Richards School many bulbs are not producing maximum light output.
Disucssion: Illumination refers ro the quantity of light incident on a work surface, and visual acuity generally increases with increased illumination. It is important to note that United States requirements in this regard are very high, in that they are based on performing difficult reading tasks with a high degree of acuity, and that lower standards, we believe. are quite acceptable. Mount Healthy has locations in 2 classroom areas which fall below the United States standard but which we believe are acceptable due to (a) the aforementioned 'luxurious' existing standards; (b) the tasks in the schools not approaching the criticalness of the task by which the standard was set; and (c) the openness of the school providing immediately adjacent areas where high level illumination exists. At the Richards School bulb replacement is necessary.

LIGHTING: ROOM CONTRAST RATIOS

Results: Performance levels at the Mount Healthy and Richards Schools were generally satisfactory, functioning at the 85% level. Parkside and Smith typically have poorer performance (75% or below) in this area.
Probable cause: Extensive window areas within the user's cone of vision result in high contrast ratios.
Discussion: The ratios of reflected light from larger surfaces

in a room determine the room contrast ratio. Adjacent surfaces with high contrast will produce eye muscle tension and visual fatigue. With the window shades open, room contrast ratios exceed those generally recommended. Only when the shades are fully drawn does the contrast ratio become acceptable (within 1:10 ratio). When the teacher closes the shade it is probably to eliminate direct glare, especially sky glare, and to reduce the size of the glare source.

The large windows at the Smith and Parkside Schools are the source of the very high room contrast ratios found. The Richards School windows, which are smaller (12 feet long) and in most classrooms are in the rear of the room, are most satisfactory, performing at the 95% level. They are large enough to create a 'space' for projects and activities while their location in the rear of the room and diminished size provide an adequate room contrast ratio.

LIGHTING: GLARE

Results: Performance levels at Parkside and Smith, are generally below the 75% level. Performance levels at Richards and Mount Healthy, 85% and 95% respectively, were satisfactory.
Probable cause: Intensity of the illumination created by the classroom windows.
Discussion: Room contrast ratios notwithstanding, the absolute amount of glare may be enough to provide the detrimental physiological effects described previously. An analogous, though exaggerated, situation, disability glare, occurs when looking directly into the high beam headlights of on-coming automobiles. In a classroom situation, discomfort glare results in an elevated blinking rate, muscle tension and lessened visual efficiency. Classrooms with large southern windows at the Parkside and Smith Schools receive direct glare in excess of recommended levels. Large windows at Smith and Parkside produce from 300-2000 foot-lamberts with shades open when the upper limit is reasonably

400 foot-lamberts. Shades are often drawn only halfway to screen out sky glare which is in the 1000-3000 foot-lamberts range. Glare from lighting fixtures was not a problem in any of the schools due to the use of adequate diffusers and shielding of the bulbs. At Mt. Healthy, though, no diffuser is used on flourescent luminaires, they are above the normal cone of vision.

LIGHTING: TASK/IMMEDIATE SURROUND CONTRAST RATIOS

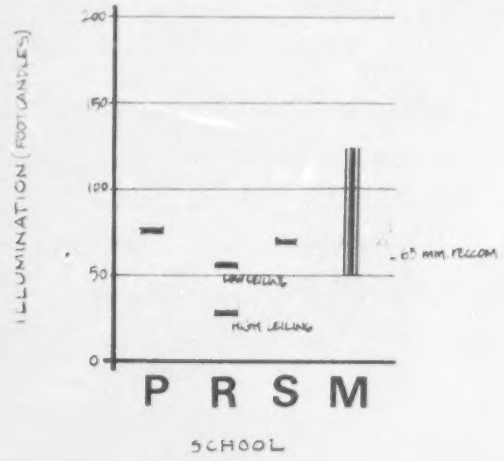
Results: Satisfactory in all schools.
Probable cause: Not applicable
Discussion: Due to the light colors chosen for desk tops and flooring materials.

LIGHTING: DARKENED ROOM

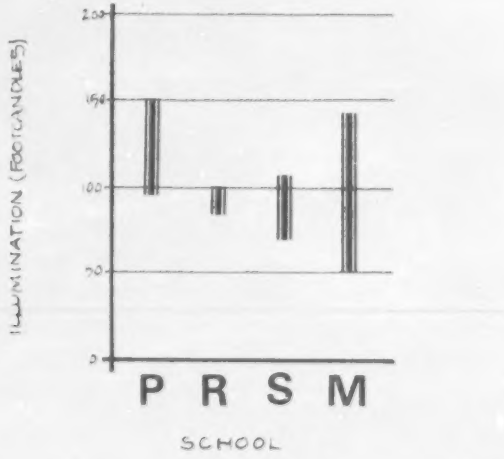
Results: Satisfactory at Smith, and Richards Schools.
Unsatisfactory (below 75% performance) at Parkside School.
Probable cause: Shades are semi-opaque
Discussion: Measurements in Parkside classrooms with south orientations produced readings over 300 foot-lamberts on the shades in bright sunlight which is detrimental to audio visual as insufficient contrast is produced in the image. Six footlamberts were read on the screen and from 4-11 footcandles in the classroom.

The Richards and Smith Schools produced 0 footcandles (almost complete darkness) which is satisfactory.

G.1 ILLUMINATION/ARTIFICIAL LIGHTING/CLASSROOMS



G.2 ILLUMINATION/ARTIFICIAL & NATURAL LIGHTING/CLASSROOMS



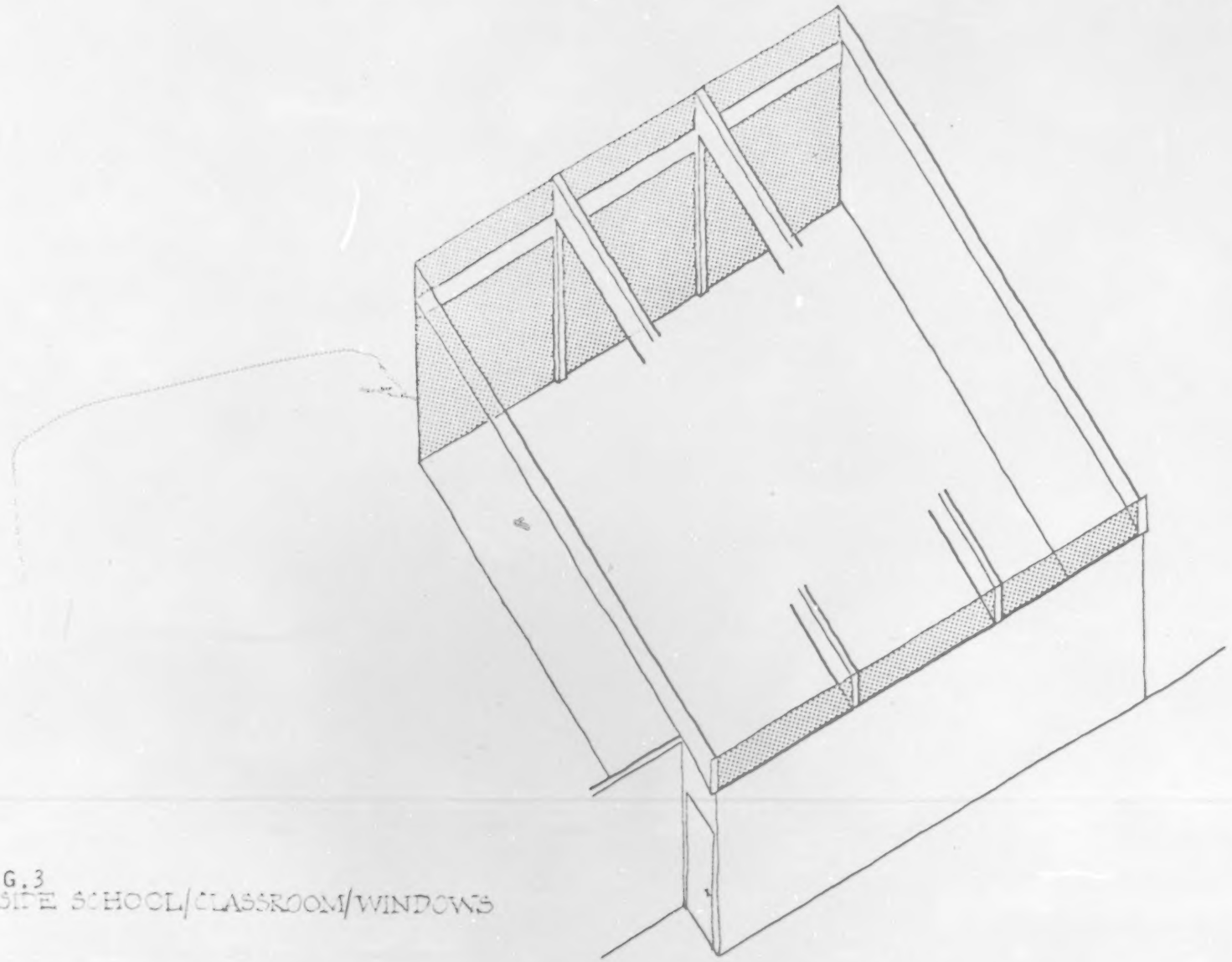


fig. G.3
PARKSIDE SCHOOL/CLASSROOM/WINDOWS

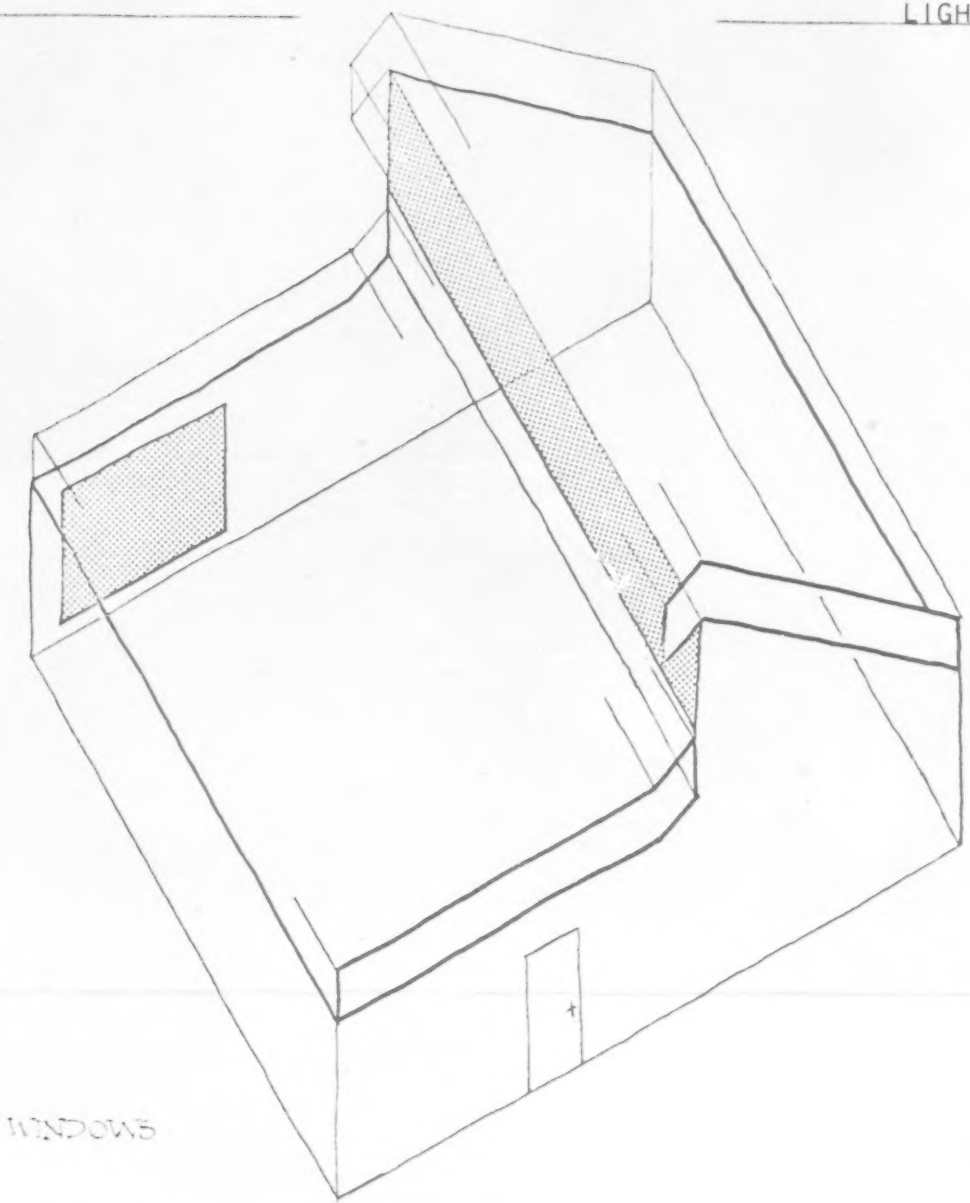


fig. G.4
NUHARDS SCHOOL/CLASSROOM/WINDOWS

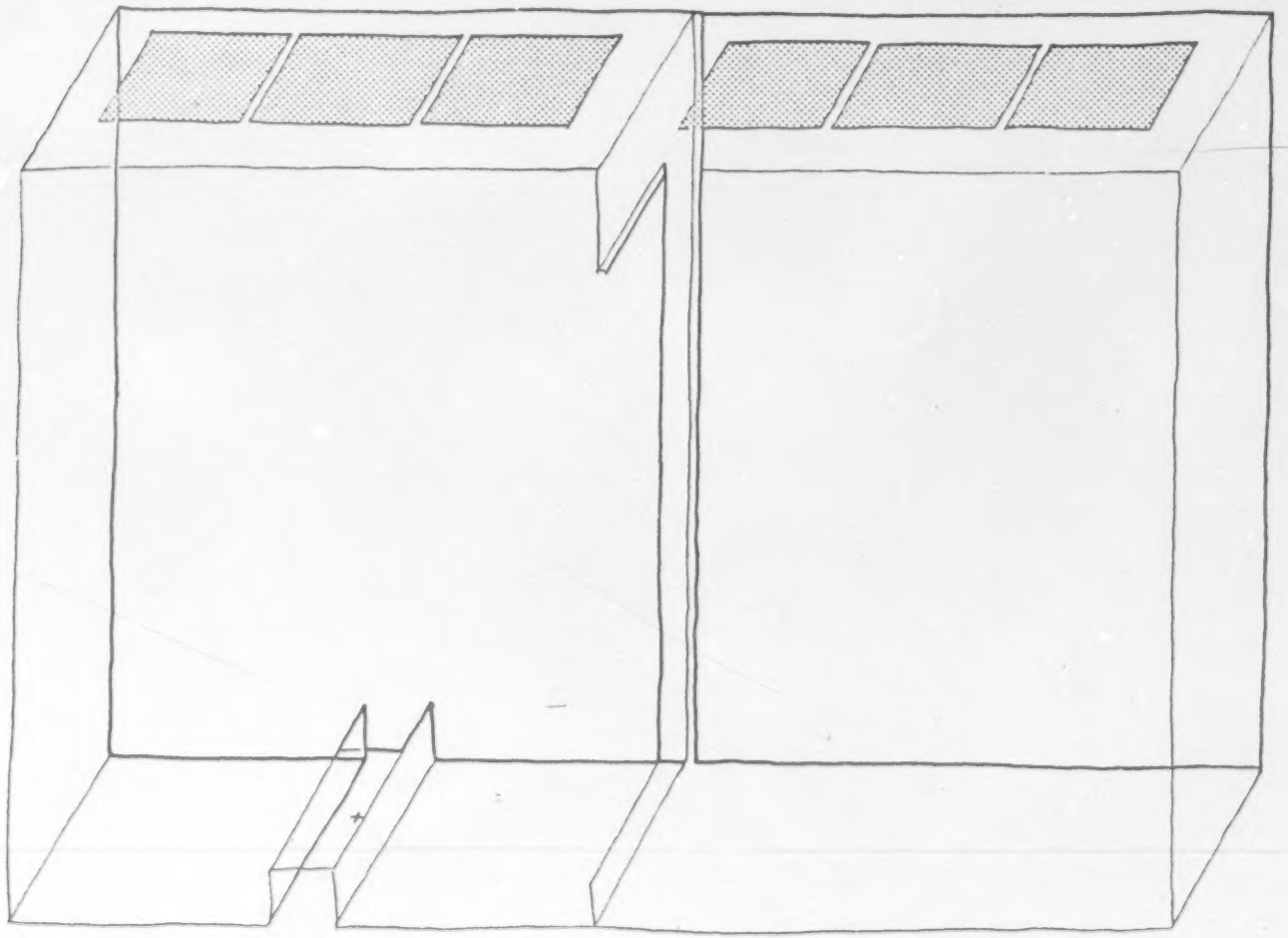
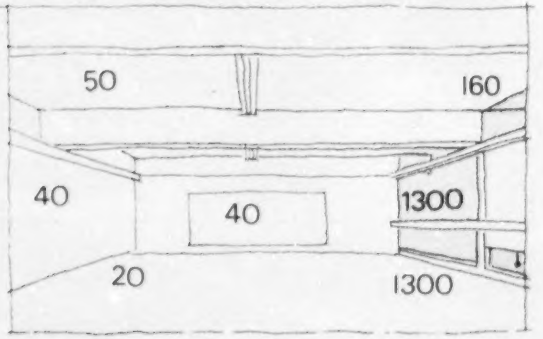
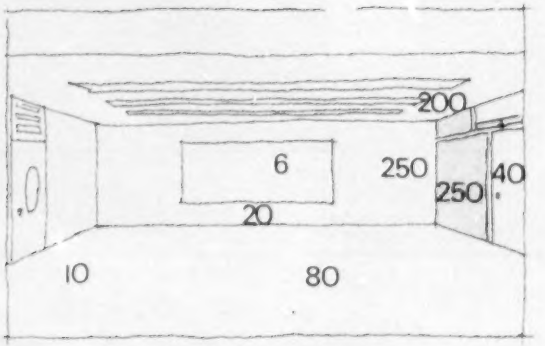


fig. G.5
SMITH SCHOOL/DOUBLE CLASSROOM/WINDOWS

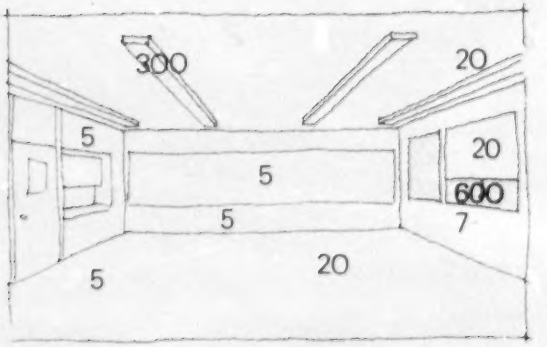
LUMINANCE/CLASSROOMS
figures are in footlamberts



G.6 PARKSIDE SOUTH - BRIGHT SUN



G.7 RICHARDS SOUTH - CLOUDY



G.8 SMITH SOUTH - CLOUDY BRIGHT

HVAC

INTRODUCTION

The proper design of the Heating, ventilating and air conditioning subsystem will determine the thermal comfort of a building's inhabitants. The comfort range is relatively small and deviations from it are easily perceived. The major determinant is the ambient temperature but drafts and radiative effects also have an influence on comfort, sometimes notwithstanding proper ambient temperature.

Added complexity in the design of HVAC subsystems is the variance in heating or cooling load needed throughout any one building - what is usually referred to as zoning. This requires the subsystem to deliver different temperatures of the heating cooling medium to many areas of the facility.

METHOD OF EXAMINATION

The quality of the thermal environment was measured by using a temperature recorder. Since cooling is not provided in the 3 older schools this was the factor most closely studied. Determining the performance of the following characteristic and comparing it with recommended standards results in an evaluation of the quality of the thermal environment. For a more detailed description refer to the Field Test Manual, December 1974.

SUMMARY OF PERFORMANCE

	P	R	S	M
Ambient Temperature	⊙	⊙	⊙	○

SUMMARY OF FINDINGS

Performance of HVAC systems is unsatisfactory during the beginning and end of the school year at the Parkside, Richards and Smith Schools. Mt. Healthy School has cooling capability and is satisfactory.

DETAILS OF FINDINGS

AMBIENT TEMPERATURE

Results: In the 3 schools without cooling systems the classroom temperatures exceed maximum recommended limits (78 degrees) from approximately mid-May through schools' closing date in early June. During the first 2-3 weeks of school in September this result can also be expected.
Probable cause: Lack of cooling capability.
Discussion: Since these schools are closed during the summer months the need for cooling capacity can be questioned. For about 6 weeks real discomfort will be experienced. It is possible in each school, we believe, to add on some cooling capacity without major alterations though this area needs more study. In the interim most teachers bring in their own fans to produce some cooling by convection during this period.

OTHER AREAS

A warm weather ambient temperature study was our focus in the HVAC area. Further research needs to be done especially on the radiative effects of the uninsulated walls in the winter. Informal observations and a questionnaire given to teachers in two of the schools (without cooling) note virtually no problems with winter heating and unanimous dissatisfaction with hot weather.

INDOOR AMBIENT TEMPERATURE